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FRESHWATER GOBIES IN THE ADRIATIC DRAINAGE BASIN OF THE WESTERN BALKANS

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ABSTRACT

The knowledge of the west Balkan freshwater gobies in the Adriatic drainage basin is still poor and insufficient for their adequate and effective conservation. New data on geographical and ecological distribution of freshwater gobies in the Adriatic drainage basin of the West Balkans are provided. A considerable extension of the known range in this area is demonstrated for Knipowitschia caucasica, Padogobius bonelli *and* Pomatoschistus canestrinii. *For the first time,* Knipowitschia radovici *and* Knipowitschia croatica *have been reported from the River Neretva catchment in Bosnia and Herzegovina. The find of* K. radovici *is, so far, the second known record of this species.* Pomatoschistus montenegrensis *is reported from Albania for the first time.*

Key words: Gobiidae, geographic distribution, ecological distribution, Adriatic drainage, Western Balkans

GHIOZZI D'ACQUA DOLCE NEL BACINO IDROGRAFICO ADRIATICO DEI BALCANI OCCIDENTALI

SINTESI

La conoscenza dei ghiozzi d'acqua dolce dei Balcani occidentali nel bacino idrografico Adriatico è ancor sempre scarsa ed insufficiente per una conservazione adeguata ed effettiva di tali specie. L'articolo fornisce nuovi data sulla distribuzione geografica ed ecologica dei ghiozzi d'acqua dolce nel bacino idrografico Adriatico dei Balcani occidentali. Viene dimostrata un'estensione considerevole della distribuzione fino ad oggi nota per le specie Knipowitschia caucasica, Padogobius bonelli *e* Pomatoschistus canestrinii. *Viene inoltre riportata per la prima volta la presenza di* Knipowitschia radovici *e* Knipowitschia croatica *nel fiume Neretva, in Bosnia ed Erzegovina. Per* K. radovici *si tratta inoltre della seconda segnalazione in assoluto.* Pomatoschistus montenegrensis *viene segnalato per la prima volta in Albania.*

Parole chiave: Gobiidae, distribuzione geografica, distribuzione ecologica, bacino idrografico Adriatico, Balcani occidentali

INTRODUCTION

The knowledge on the west Balkan freshwater gobies in the Adriatic drainage basin has been extended considerably in the recent years. Four new species have been described (Kovačić, 2005a; Kovačić & Šanda, 2007; Miller & Šanda, 2008; Miller, *in press*), and new data on morphology, ecology and distribution of already known species published (Kovačić & Pallaoro, 2003; Kovačić, 2005b). So far, eight freshwater gobies have been recorded for this area. This includes *Knipowitschia mrakovcici* Miller, 2009 from the River Krka, a species known since 1989, but described only recently (Mrakovčić *et al.*, 1994; Miller, 2009). Most of these species are endemic, restricted to small isolated freshwater habitats and vulnerable to human threats. However, the knowledge on their taxonomy, geographical and ecological distribution, as well as on their life histories and present human-induced threats is far from the level that could enable their effective conservation and could prevent species extinction. The aim of this paper is to provide information on the extended geographical and ecological distribution of the West Balkan freshwater gobiid species, based on the positive identification of our material, as well as of the published data, and on the published information on the deposition of the collected material.

MATERIAL AND METHODS

Fishes were collected by electrofishing or by hand net during scuba-diving. The examined material is deposited in the National Museum Prague (NMP) and in the Rijeka Natural History Museum (Prirodoslovni muzej Rijeka – PMR). The data on all used material are listed for each species in the Results section.

The identification was carried out using identification keys and the so far published species descriptions (Miller, 2003, 2004; Kovačić, 2005a; Kovačić & Šanda, 2007; Miller & Šanda, 2008). The head lateral line system was checked using a binocular. When necessary, the specimens were stained in 2% $KMnO_4$ solution for 20 s and 0.3% H_2SO_4 solution for 20 s, which allowed a better examination of sensory papillae rows. The diagnoses are a minimum combination of characters that positively identify researched specimens among the European and Ponto-Caspian gobiid species (Miller, 2003, 2004; Kovačić, 2005a; Kovačić & Šanda, 2007; Miller & Šanda, 2008). Morphometric and meristic methods follow Miller (1988). The meristic abbreviations: A, anal fin; C, caudal fin; D, dorsal fins; P, pectoral fin; V, pelvic disc; LL, scales in lateral series; TR, scales in transverse series. The terminology of lateral-line system follows Sanzo (1911), Economidis & Miller (1990) and Miller (2004).

The published data on gobiid species are considered to have a positive identification when the following criteria have been met: the specimens are deposited in collections, or the published description contains enough morphological data for a positive identification. All other published data were cited separately and discussed in the remarks. The information on the ecological distribution was based on the published data and our data from the new records.

RESULTS

Knipowitschia caucasica (Berg, 1916)

Material examined. 10 specimens, PMR VP1113, River Zrmanja, Jankovića buk, Dalmatia, Croatia, 44° 12′10.3′′ N, 15°43′17.2′′ E, 18 October 2002; 10 specimens, PMR VP1114, River Zrmanja, between Obrovac and the river mouth, Dalmatia, Croatia, 44°13′1.2′′ N, 15°38′30.5′′ E, 18 October 2002; 10 specimens, PMR VP1119, River Krka, Žurići, Dalmatia, Croatia, 43°49′ 12.4′′ N, 15°56′11.7′′ E, 7 May 2003; 1 specimen, PMR VP1289, Desansko lake, drainage of the River Neretva, Dalmatia, Croatia, 43°3′4.8′′ N, 17°31′4.8′′ E, 22 June 2004; 1 specimen, PMR VP1390, mouth of the River Raša, Istria, Croatia, 45°4′25.6′′ N, 14°2′0.5′′ E, 23 May 2005; 1 specimen, PMR VP1399, mouth of the River Raša, Istria, Croatia, 45°2′57.2′′ N, 14°2′56.2′′ E, 22 September 2005; 1 specimen, PMR VP1400, mouth of the River Raša, Istria, Croatia, 45°3′37.7′′ N, 14°2′34′′ E, 22 September 2005; 1 specimen, PMR VP1985, Privlaka, near Zadar, Dalmatia, Croatia, 44°16′37.6′′ N, 15°7′41. 3′′ E, 26 April 2008.

Diagnosis. (1) sensory papillae with suborbital row *a*, (2) interorbit without two or more transverse rows of papillae, (3) the anterior oculoscapular and preopercular canals present, (4) coloration not uniformly black above, (5) the posterior oculoscapular canal present at least in a part of the population, (6) the scales beginning anteriorly from the rear end of D1 at least in a part of the population.

Distribution. (Fig. 1) Published data: Dinjiška on Pag Island, River Karišnica flowing into Karinsko Sea, Karinsko Sea, Vransko Lake, Pirovac in Pirovački Bay, Prokljansko Lake in Krka River basin, River Jadro in Morinj Bay near Šibenik, River Pantan near Trogir, River Cetina near Omiš, all in Croatia (Kovačić & Pallaoro, 2003).

New data: the mouth of the River Raša on Istria, Privlaka near Zadar, River Zrmanja between Obrovac and its mouth to the sea and in Jankovića buk, River Krka in Žurići, Desansko Lake in the River Neretva catchment, all in Croatia. The knowledge about the range of *K. caucasica* in the Adriatic Sea basin was considerably extended. Previously published data delimit the known area of occurrence to the northern and cen-

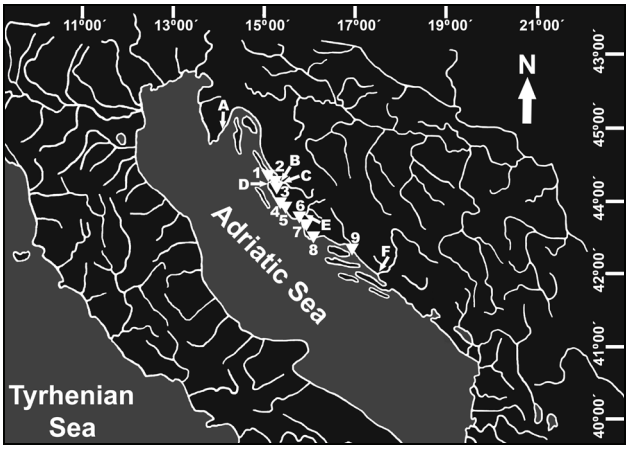

***Fig. 1: The occurrence of** Knipowitschia caucasica **in the Adriatic drainage basin of the Western Balkans. ▼ indicates published records (Kovačić & Pallaoro, 2003): 1 – Dinjiška on Pag Island; 2 – Karinsko Sea; 3 – River Karišnica; 4 – Vransko Lake; 5 – Pirovac in Pirovački Bay; 6 – Prokljansko Lake; 7 – River Jadro in Morinj Bay, 8 – River Pantan; 9 – River Cetina. New records are indicated by arrows: A – mouth of the River Raša; B – River Zrmanja between Obrovac and mouth to the sea; C – River Zrmanja in Jankovića buk; D – Privlaka; E – River Krka in Žurići; F – Desansko Lake.*
Sl. 1: Pojavljanje vrste** Knipowitschia caucasica **v Jadranskem povodju zahodnega Balkana. ▼ ponazarja objavljene podatke (Kovačić & Pallaoro, 2003): 1 – Dinjiška na otoku Pagu; 2 – Karinsko morje; 3 – Reka Karišnica; 4 – Vransko jezero; 5 – Pirovac v Pirovačkem zalivu; 6 – Prokljansko jezero; 7 – Reka Jadro pri Morinjskem zalivu, 8 – Reka Pantan; 9 – Reka Cetina. Novi podatki so označeni s puščicami: A – ustje reke Raše; B – Reka Zrmanja med Obrovcem in njenim ustjem v morje; C – Reka Zrmanja pri Jankovića buku; D – Privlaka; E – Reka Krka pri Žurićih; F – Desansko jezero.

tral Dalmatia, from the southern coast of the Island Pag to the River Cetina catchment (Kovačić & Pallaoro, 2003). An intensive research revealed presence of this species in the River Neretva catchment and in the waters of the Istrian peninsula, as well as in several new places within the previously known range.

Ecological distribution. Euryhaline species, found in brackish running to slowly running waters: mouths of rivers, springs by the sea, small lagoons or tidal pools, sea-influenced parts of rivers. Found in places with highly variable bottom: mud, sand, gravel or boulders, bare or covered with algae or *Zostera* spp.

Remarks. The range of *K. caucasica* is very large, including brackish coastal waters of the Caspian, Black, Aegean, the eastern Ionian (Miller *et al.*, 2004) and the eastern Adriatic Seas (Kovačić & Pallaoro, 2003). There is a considerable hiatus in the distribution of *K. caucasica* from the River Neretva estuary to the River Acheloos in Greece. Some authors suggest that the Adriatic basin is inhabited by *K. pannizae* (Economidis & Miller, 1990; Miller *et al.*, 2004; Kottelat & Freyhof, 2007). Recognizing the described high variability in morphological characters of the Adriatic populations of *K. caucasica* (Kovačić & Pallaoro, 2003), it is not always possible to positively distinguish between *K. caucasica* and *K. panizzae*. Further investigations, including detailed morphological and molecular analyses, are necessary to solve this problem. However, the studied populations of the Adriatic *K. caucasica* clearly differ from the published description of *K. panizzae* (Miller, 1972) (see diagnosis).

Knipowitschia croatica Mrakovčić, Kerovec, Misetić, Schneider, 1996

Material examined. 10 specimens, PMR VP1599**,** River Matica, Polje Rastoka, Croatia, 43°12′29.5′′ N, 17° 23′57.6′′ E, 14 October 2006; 10 specimens, PMR VP1613**,** River Matica, Polje Rastoka, Croatia, 43°12′ 51.1′′ N, 17°25′14.9′′ E, 19 October 2006; 27 specimens, NMP P6V 85605-85610, 85613-85627, 85628-85633, channel in Hutovo Blato wetland, Bosnia and Herzegovina, 43°03′51.5′′ N, 17°45′18.8′′ E, 23 July 2004, 13 July 2006 and 24 September 2008; 2 specimens, NMP P6V 85611-85612, River Trebižat above Kravica waterfalls, Bosnia and Herzegovina, 43°9′38.5′′ N, 17°36′45.1′′ E, 22 July 2004; 3 specimens, NMP P6V 84588-84590, River Trebižat in Teskera, Bosnia and Herzegovina, 43°11′0.9′′ N, 17°31′21′′ E, 14 July 2006.

Diagnosis. (1) sensory papillae with suborbital row *a*, reaching anteriorly at least below anterior edge of pupil, (2) head canals absent, (3) interorbit without multiple transverse rows of papillae, (4) body squamation reduced to axillar patch, (5) D1 modally VI, (6) A I/8.

Distribution. (Fig. 2) Published data: River Matica in karst field Polje Jezero, Bačina Lakes, Modro oko Lake, River Norin, all in Croatia (Mrakovčić *et al.*, 1996).

New data: karst field Polje Rastoka, Croatia; channel in Hutovo Blato wetland, River Trebižat above Kravica waterfalls, River Trebižat in Teskera, all in Bosnia and Herzegovina. The occurrence of *K. croatica* is reported for the first time from several localities in Bosnia and Herzegovina, as well as from the karst field Rastoka in Croatia. The known distribution area covers the lower River Neretva basin up to the town of Čapljina and karst fields Jezero and Rastoka. To be able to confirm the presence of *K. croatica* in the River Neretva upstream of Čapljina and in its inflow Bregava, as well as in the River Trebižat upstream of village Teskera, further investigation is required.

Ecological distribution. Oligotrophic karst waters, both slowly running and stagnant. In fresh and slightly

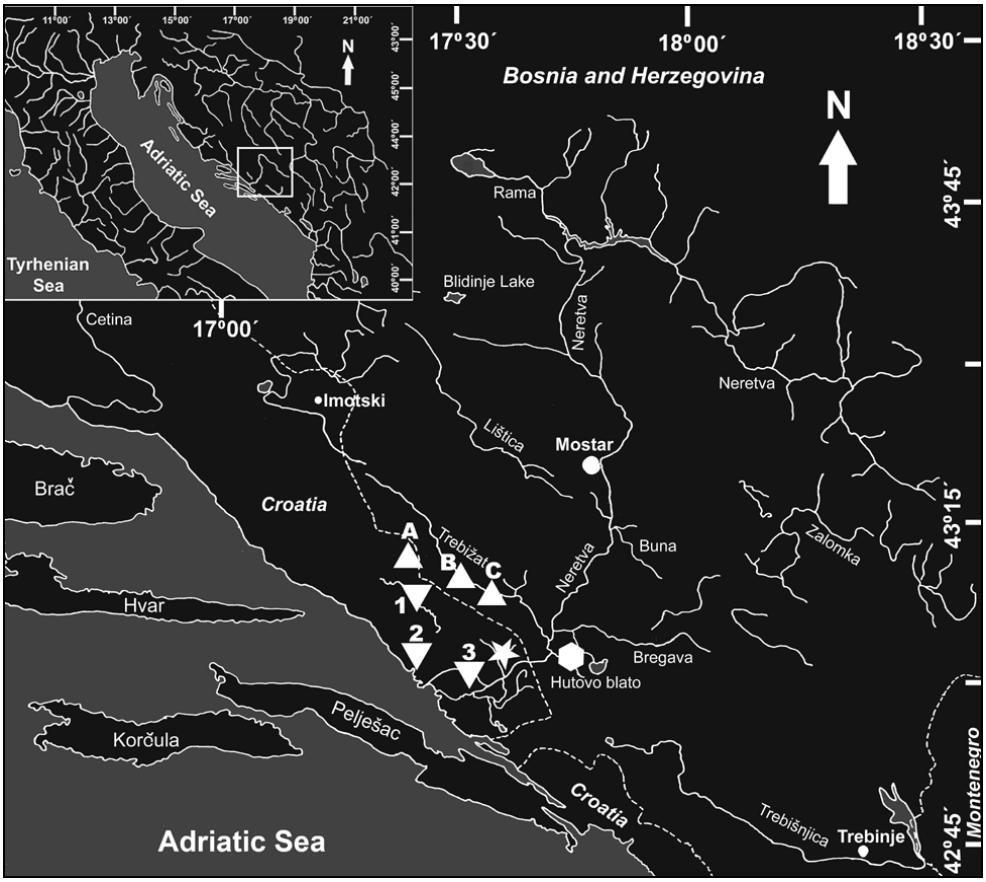

Fig. 2: The occurrence of *Knipowitschia croatica* ***and*** *K. radovici* ***in the Adriatic drainage basin of the Western Balkans. ▼ indicates published records of*** *K. croatica* ***(Mrakovčić*** *et al.****, 1996): 1 – River Matica in karst field Polje Jezero; 2 – Bačina Lakes; 3 – Modro oko Lake. ★ is River Norin, where both*** *K. croatica* ***and*** *K. radovici* ***were found (Mrakovčić*** *et al.****, 1996; Kovačić, 2005a). New records of*** *K. croatica* ***are indicated by ▲: A – karst field Polje Rastoka; B – River Trebižat in Teskera; C – River Trebižat above Kravica waterfalls. Hexangle marks channel in Hutovo Blato wetland, where both*** *K. croatica* ***and*** *K. radovici* ***were found.***
Sl. 2: Pojavljanje vrst *Knipowitschia croatica* ***in*** *K. radovici* ***v Jadranskem povodju zahodnega Balkana. ▼ ponazarja objavljene podatke o vrsti*** *K. croatica* ***(Mrakovčić*** *et al.****, 1996): 1 – Reka Matica na kraškem polju Jezero; 2 – Bačinska jezera; 3 – Jezero Modro oko. ★ je reka Norin, kjer sta bili odkriti vrsti*** *K. croatica* ***in*** *K. radovici* ***(Mrakovčić*** *et al.****, 1996; Kovačić, 2005a). Novi zapisi o vrsti*** *K. croatica* ***so označeni z ▲: A – kraško polje Rastoka; B – Reki Trebižat in Teskera; C – Reka Trebižat nad slapovi Kravica. Šesterokotnik označuje kanal v mokrišču Hutovo blato, kjer sta bili odkriti vrsti*** *K. croatica* ***in*** *K. radovici****.***

brackish waters (0–0.05‰), it tolerates temperatures of up to at least 24°C. Found in places with muddy and sandy bottom, both bare and covered with vegetation.

Remarks. Vuković (1977) published information on the presence of several gobies *(Padogobius panizzai, Pomatoschistus canestrini, P. microps* – the names are given exactly in the form used in the original publication) in the lower River Neretva in Bosnia and Herzegovina. It could partially refer to this species. Other published data without a diagnosis or the collection numbers: lakes Svitava and Deran in Hutovo Blato wetland, Bosnia and Herzegovina (Dulčić *et al.*, 2008; Glamuzina *et al.*, 2008).

Knipowitschia radovici Kovačić, 2005

Material examined. 7 specimens, NMP P6V 85634-85640, channel in Hutovo Blato wetland, Bosnia and Herzegovina, 43°3′51.5′′ N, 17°45′18.8′′ E, 23 July 2004 and 24 September 2008.

Diagnosis. (1) sensory papillae with suborbital row *a*, (2) interorbit without two or more transverse rows of papillae, (3) squamation reduced to axillar and caudal peduncle patches, unconnected or connected with single row along lateral midline, (4) the anterior oculoscapular canal present, ending anteriorly with or without pore λ, and the preopercular canal present, at least in a part of

population, (5) coloration without numerous small, but intense black spots in males.

Distribution. (Fig. 2) Published data: known only from its type locality, the River Norin, an inflow of the River Neretva in Croatia (Kovačić, 2005a).

New data: It was found for the first time in Bosnia and Herzegovina, in a channel in Hutovo Blato wetland in the River Neretva catchment. This place is located only 10 km aerial distance from the type locality.

Ecological distribution. Found only in oligothrophic karst freshwaters, both in running and almost stagnant. Juveniles were found in littoral areas with vegetation, together with *K. croatica*, whereas adults were collected in deep water in the flow. The bottom in the flow was made of gravel, changing to mud laterally in the case of the River Norin, while it was composed of fine sediment covered amply with woody debris in the case of the channel in Hutovo Blato. This species tolerates temperatures of up to at least 24°C.

Remarks. Vuković (1977) published information on the presence of several gobies *(Padogobius panizzai, Pomatoschistus canestrini, P. microps* – the names are given exactly in the form used in the original publication) in the lower Neretva in Bosnia and Herzegovina. This work could partially refer to this species. Glamuzina *et al*. (2008) and Dulčić *et al*. (2008) referred to the presence of undescribed *Knipowitschia* species found in lakes Svitava and Deran in Hutovo Blato wetland, Bosnia and Herzegovina. Their *Knipowitschia* sp. is most probably *K. radovici*. The distribution of *K. radovici* in the lower River Neretva catchment needs further investigation.

Padogobius bonelli (Bonaparte, 1846)

Material examined. 10 specimens, PMR VP1052, Stream Dobarnica, Dalmatia, River Zrmanja catchment, Croatia, 44°12′0′′ N, 15°46′12′′ E, 17 October 2002; 4 specimens, PMR VP1053, River Zrmanja, Ogari, Croatia, 44°11′34′′ N, 15°47′22′′ E, 17 October 2002; 7 specimens, PMR VP1054, River Zrmanja, Kaštel Žegarski, Croatia, 44°9′38′′ N, 15°51′15′′ E, 16 October 2002; 10 specimens, PMR VP1116, River Zrmanja, Berberi buk, Dalmatia, Croatia, 44°11′46′′ N, 15°46′6′′ E, 17 October 2002; 8 specimens, PMR VP1406, River Mirna, Sv. Ivan, Buzet, Istria, Croatia, 45°23′54.6′′ N, 13°58′47.2′′ E, 19 September 2005; 10 specimens, PMR VP1408, River Mirna, Motovun, Istria, Croatia, 45°20′47.5′′ N, 13°49′ 44′′ E, 20 September 2005; 2 specimens, PMR VP1409, River Mirna, between Veliki Mluni and Mali Mluni, Istria, Croatia, 45°23′33.9′′ N, 13°54′45.5′′ E, 20 September 2005; 10 specimens, PMR VP1407, Stream Račički, Mirna drainage, Istria, Croatia, 45°21′42.7′′ N, 13°51′ 19.2′′ E, 23 September 2005; 1 specimen, PMR VP1988, lower part of the River Ričica, 44°23′12.7′′ N, 15°44′ 58.1′′ E, Lika, Croatia, 28 June 2008.

Diagnosis. (1) sensory papillae without suborbital row *a*, (2) scales normal, (3) no free pectoral rays, (4) anterior nostril not elongate beyond upper lip, (5) no scales on anterior nape, (6) head canals absent.

Distribution. (Fig. 3) Published data: Occurrence of *P. bonelli* (under the name *P. martensii)* was reported from the lower River Zrmanja catchment and the lower Krka catchment (near Krka–Čikola waterfalls), all in Croatia (Bianco & Miller, 1990).

New data: It was found in the River Zrmanja considerably further upstream from the previously published locality. It was also found in several places within the River Mirna catchment in Istrian peninsula. Furthermore, it was found in the River Ričica, belonging to the River Lika catchment, where it had been most probably introduced. The presented data confirmed the previously supposed presence in the River Mirna basin (see remarks) and extended the knowledge about the species' occurrence in the River Zrmanja basin.

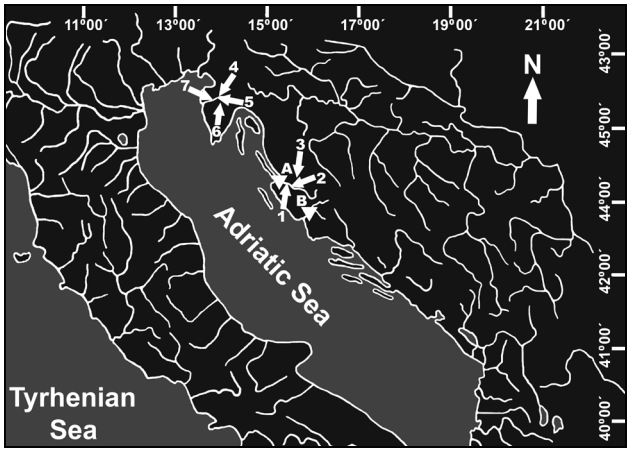

Fig. 3: The occurrence of** Padogobius bonelli **in the Adriatic drainage basin of the Western Balkans. ▼ indicates published records (Bianco & Miller, 1990): A – lower part of the River Zrmanja; B – River Krka near Krka–Čikola waterfalls. New records are indicated by arrows: 1 – closely located places in the River Zrmanja drainage (River Dobarnica, Ogari and Berberi buk); 2 – River Zrmanja in Kaštel Žegarski; 3 – River Ričica, Lika drainage; 4 to 7 – River Mirna drainage (4 – Buzet; 5 – between Veliki Mluni and Mali Mluni; 6 – Račički Stream; 7 – Motovun).

Sl. 3: Pojavljanje vrste** Padogobius bonelli **v jadranskem povodju zahodnega Balkana. ▼ ponazarja objavljene podatke (Bianco & Miller, 1990): A – spodnji tok reke Zrmanje; B – Reka Krka pri slapovih Krka–Čikola. Novi podatki so označeni s puščicami: 1 – lokacije v povodju reke Zrmanje (reka Dobarnica, Ogari in Berberi buk); 2 – Reka Zrmanja pri Kaštelu Žegarskem; 3 – Reka Ričica, povodje Like; 4 to 7 – Povodje reke Mirne (4 – Buzet; 5 – med Velikimi Mluni in Malimi Mluni; 6 – Potok Račički; 7 – Motovun).

Ecological distribution. Freshwater species, present mainly in running waters of rivers and springs. Bottom: bare pebbles, boulders, bedrock or with scattered vegetation. Exceptional was its discovery in the muddy, slowly running water of the River Ričica in the Lika catchment.

Remarks. Several gobiid species were reported for the River Mirna in the various species lists published for Istria or Croatia in general: *Padogobius martensii, Knipowitschia pannizai, P. panizzae* (Leiner & Povž, 1993, 1994; Mrakovčić *et al.*, 1994; Leiner *et al.*, 1995). We believe that all these finds refer to the population of *P. bonelli* from the Mirna River. The presence of this species in the River Ričica, the Lika catchment, is probably a result of introduction or of a passive transference with water taken by the system of the reversible hydroelectric power plant Obrovac.

Pomatoschistus canestrinii (Ninni, 1883)

Material examined. 1 specimen, PMR VP1290, River Norin, Vid, catchment of the River Neretva, Dalmatia, Croatia, 43°4′52.8′′ N, 17°37′54.8′′ E, 24 June 2004; 5 specimens, PMR VP1291, Desansko Lake, catchment of the River Neretva, Dalmatia, Croatia, 43°3′4.8′′ N, 17° 31′4.8′′ E, 22 June 2004; 7 specimens, PMR VP1292, Modro oko, catchment of the River Neretva, Dalmatia, Croatia, 43°3′26.7′′ N, 17°30′37′′ E, 21 June 2004; 10 specimens, PMR VP1293, Kuti Lake, catchment of the River Neretva, Dalmatia, Croatia, 42°57′1.9′′ N, 17°36′ 47.7′′ E, 22 June 2004; 1 specimen, PMR VP1294, River Neretva, near Bijeli vir, Dalmatia, Croatia, 43°0′27.7′′ N, 17°38′59.4′′ E, 22 June 2004; 10 specimens, PMR VP1374, mouth of the River Mirna, Istria, Croatia, 45°19′24.7′′ N, 13°36′14.4′′ E, 25 May 2005; 10 specimens, PMR VP1384, mouth of the River Raša, Istria, Croatia, 45°13′3.6′′ N, 14°3′43.2′′ E, 23 May 2005; 6 specimens, PMR VP1402, River Raša, near Kunj, Istria, Croatia, 45°4′30.9′′ N, 14°2′4.5′′ E, 22 September 2005; 7 specimens, PMR VP1405, River Mirna, near Sv. Dionizije, 45°20′7.6′′ N, 13°39′9.6′′ E, 20 September 2005.

Diagnosis. (1) sensory papillae with suborbital row *a*, (2) interorbit without two or more transverse rows of papillae, (3) squamation never reduced just to axillar patch, (4) the anterior oculoscapular canal always present, the preopercular and posterior oculoscapular head canals of variable occurrence, (5) coloration with numerous small, but intense black spots in males.

Distribution. (Fig. 4) Published data: Occurrence of *P. canestrinii* was reported from the lower River Zrmanja catchment up to village Nadvoda, the lower River Krka up to Skradinski buk, the rivers Jadro and Žrnovnica near Split, the lowermost part of the River Cetina and Bačinska Lakes in the River Neretva catchment, all in Croatia (Kovačić, 2005b).

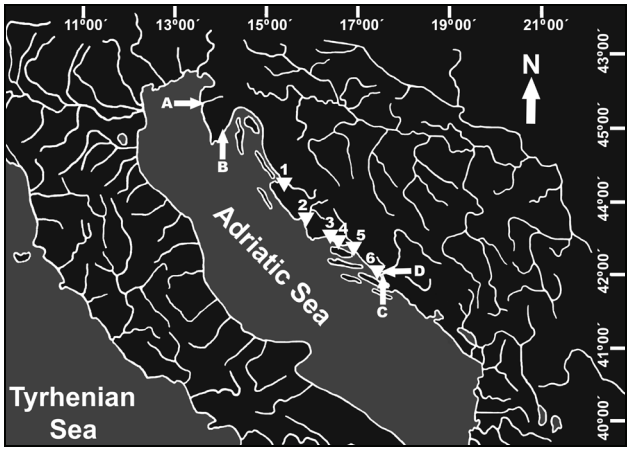

***Fig. 4: The occurrence of** Pomatoschistus canestrinii **in the Adriatic drainage basin of the Western Balkans. ▼ indicates published records (Kovačić, 2005b): 1 – lower part of the River Zrmanja; 2 – lower part of the River Krka; 3 – River Jadro; 4 – River Žrnovnica; 5 – lowermost part of the River Cetina; 6 – Bačinska Lakes. New records are indicated by arrows: A – River Mirna (mouth to the sea and in Sv. Dionizije); B – River Raša (mouth to the sea and in Kunj); C and D – localities in the lower River Neretva drainage (C – River Neretva near Bijeli Vir and Kuti Lake; D – River Norin, lakes Desansko and Modro oko).*
Sl. 4: Pojavljanje vrste** Pomatoschistus canestrinii **v Jadranskem povodju zahodnega Balkana. ▼ ponazarja objavljene podatka (Kovačić, 2005b): 1 – spodnji tok reke Zrmanje; 2 – spodnji tok reke Krke; 3 – Reka Jadro; 4 – Reka Žrnovnica; 5 – skrajni spodnji tok reke Cetina; 6 – Bačinska jezera. Novi podatki so označeni s puščicami: A – reka Mirna (ustje pri kraju Sv. Dionizije); B – reka Raša (ustje v morje in pri Kunju); C in D – lokalitete v povodju reke Neretve (C – reka Neretva pri Bijelem Viru in jezero Kuti; D – reka Norin, Desansko jezero in jezero Modro oko).

New data: It was found at several localities within the lower River Neretva catchment in Croatia (River Norin, River Neretva near Bijeli Vir, lakes Desansko, Modro oko and Kuti) and in the rivers Mirna and Raša on the Istrian peninsula. This considerably extends the knowledge about the occurrence of this species in the studied area.

Ecological distribution. Brackish (river mouths, sea-influenced parts of rivers and lakes) to freshwater parts of rivers separated from the sea by cascades; stagnant to running waters. Bottom highly variable: mud, coarse sand, gravel / pebbles, coarse sand between large rocks, boulders, mud / boulders, bare or with scattered vegetation.

Remarks. Vuković (1977) mentioned a presence of *P. canestrinii* in the lower River Neretva catchment in Bos-

nia and Herzegovina. However, there have been no reliable records of this species from this area so far. Further investigation is necessary to confirm the occurrence of *P. canestrinii* in the lower River Neretva catchment in Bosnia and Herzegovina.

***Pomatoschistus montenegrensis* Miller & Šanda, 2008**

Material examined. 8 specimens, NMP P6V 81669-81676, River Buna, Muriqan, Albania, 23 August 2004, 41°59′59.5′′ N, 19°23′09.5′′ E.

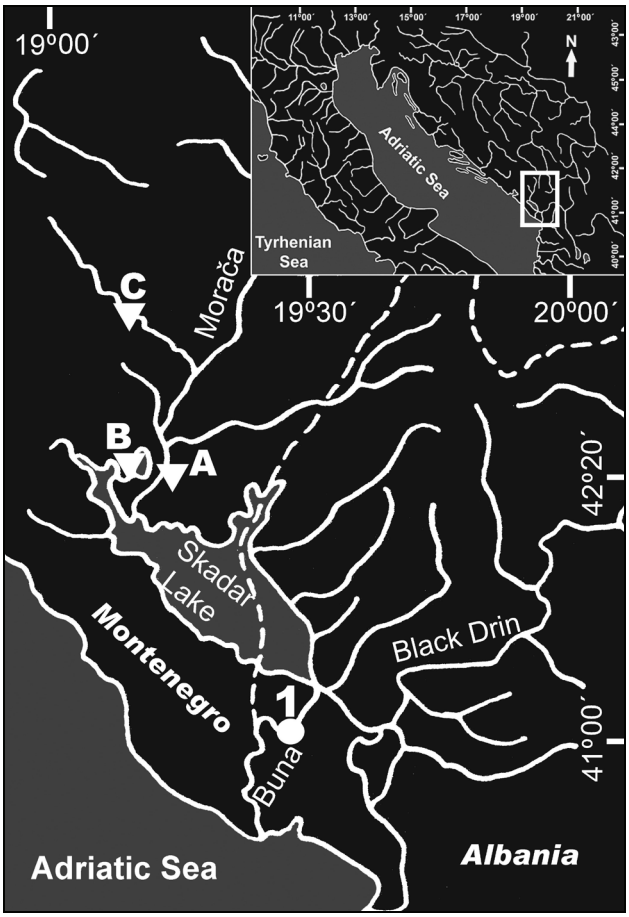

Fig. 5: The occurrence of** Pomatoschistus montenegrensis **in the Adriatic drainage basin of the Western Balkans. ▼ indicates published records: A – Morača River in Golubovci; B – Malo Blato Lake; C – River Zeta in Spuž. New record in the River Buna in Albania is marked by ● and number 1.
Sl. 5: Pojavljanje vrste** Pomatoschistus montenegrensis **v Jadranskem povodju zahodnega Balkana. ▼ ponazarja objavljene podatke: A – Reka Morača pri Golubovcih; B – Jezero Malo Blato; C – Reka Zeta pri Spužu. Novi podatek iz reke Bune v Albaniji je označen z ● in št. 1.

Diagnosis. (1) sensory papillae with suborbital row *a*, (2) interorbit without two or more transverse rows of papillae, (3) squamation reduced to axillar patch, (4) presence of the anterior oculoscapular canal, and consistent loss of the preopercular and posterior oculoscapular head canals, (5) coloration with numerous small, but intense black spots in males.

Distribution. (Fig. 5) Published data: Found in the lower River Morača and its tributary, the River Zeta in southern Montenegro, and in a large natural channel that connects Malo Blato Lake with the main body of Skadar Lake (Miller & Šanda, 2008).

New data: This species is reported from Albania for the first time, where it was found in the River Buna in Muriqan. The distribution area most probably includes Skadar Lake, its inflows and its outflow, the River Buna.

Ecological distribution. Found in freshwaters, in shallows with a slow current or in pools remaining in gravel pits after river flooding. The bottom substrate was gravel, covered with fine sediment and overgrown by dense filamentous algae or fine sediment associated with macrophytes.

Remarks. The known distribution corresponds well with the previous records of freshwater gobies identified as *K. panizzae* in Skadar Lake (Ivanović, 1973; Marić, 1995) and the lower Morača (Marić, 1995). *P. montenegrensis* may well occur throughout the whole Ohrid-Drim-Skadar system. Although later authors do not mention gobies from Ohrid Lake or the River Drim, Vinciguerra (1933) noted a freshwater goby in Lake Ohrid. Further detailed investigation is necessary to identify the range of this species.

DISCUSSION

A careful determination of recently collected material from the area of the Adriatic catchment of the Western Balkans lead to a description of four new freshwater goby species during the last five years, including *K. mrakovcici* from the River Krka, which has been known since 1989, but was just recently described (Kovačić, 2005a; Kovačić & Šanda, 2007; Miller & Šanda, 2008; Miller, 2009). However, taxonomy of some species needs further investigation. The systematic status of *K. caucasica* and *K. pannizae* urgently requires a re-evaluation (Kovačić & Pallaoro, 2003). Is *K. caucasica* a widespread species in the area from the Adriatic to the Black Seas, does the Adriatic *K. pannizae* need a redescription, or are there even more than two euryhaline *Knipowitschia* species in this large area that includes several parts of the Mediterranean and the Black Seas? The relationships of the west Balkan gobies at a generic level are in some cases also questionable. Do *P. canestrinii* and *P. montenegrensis* constitute a monophyletic assemblage, which could differ from other *Pomatoschistus* species (Miller & Šanda, 2008)? Is *Knipowitschia*

monophyletic? What are the relationships of sand goby genera (*sensu* McKay & Miller, 1997) and species?

Despite the obvious progress in the knowledge of systematics, geographic distribution and habitat of most of the species remain poorly known. Data presented in this work show that freshwater gobies from the Adriatic drainage basin of the Western Balkans belong to two groups *i.e.*, euryhaline and strictly freshwater species. Euryhaline species, *K. caucasica* and *P. canestrinii*, are the most widespread freshwater gobies in the Adriatic drainage of the Western Balkans, occurring in suitable habitats throughout the whole area. Compared to *P. canestrinii*, *K. caucasica* was found at more localities, which indicates its higher ecological valence that allowed this species to disperse through marine conditions and to colonize even isolated brackish habitats (Fig. 1). *P. canestrinii* seems to be bound more strictly to areas with stabile freshwater flow, e.g. larger rivers and non-drying up streams. The orientation of *P. canestrinii* towards the freshwater habitats is also suggested by its occurrence in purely freshwater sections of the river basins. On the other hand, *K. caucasica* was always found in at least slightly brackish habitats. The rest of the gobies from the Adriatic drainage of the Western Balkans, *e.g. K. croatica*, *K. radovici*, *P. bonelli* and *P. montenegrensis*, are freshwater species, only very rarely occurring in slightly brackish habitats. Also *K. mrakovcici* from the River Krka and *Knipowitschia montenegrina* Kovačić & Šanda, 2007, which are not presented in detail in this work, were found only in freshwaters (Mrakovčić *et al.*, 2006; Kovačić & Šanda, 2007; Miller, 2009).

The extension of the known geographic range was revealed for almost all the species of freshwater gobies from the Adriatic drainage basin of the Western Balkans. *P. canestrinii*, *K. caucasica* and *P. bonelli* were reliably documented for the first time in waters of the Istrian peninsula. Furthermore, *K. caucasica* was recorded for the first time from the River Neretva catchment and *P. bonelli* from the River Lika catchment, the former representing most probably an introduction. The remaining studied species were recorded from new localities within the basins, to which they are endemic. *P. montenegrensis* was recorded from the Skadar Lake basin in Albania, *K. radovici* and *K. croatica* from the River Neretva basin in Bosnia and Herzegovina. No new localities were recorded for *K. mrakovcici* from the River Krka basin and *K. montenegrina* from the Skadar Lake basin. *K. mrakovcici* is known from Visovačko Lake (Miller, 2009) and *K. montenegrina* from the River Morača in Montenegro (Kovačić & Šanda, 2007).

In large river basins in the Adriatic drainage basin of the Western Balkans, usually several gobies occur, partially in sympatry. In the River Neretva basin, *K. caucasica*, *K. croatica*, *K. radovici* and *P. canestrinii* were found. In the River Krka basin, *K. mrakovcici, K. caucasica*, and *P. canestrinii* were found by the authors, and *P. bonelli* was reported by Bianco & Miller (1990). In the River Zrmanja basin, *K. caucasica*, *P. bonelli* and *P. canestrinii* were recorded. The same species were recorded in waters of the Istrian peninsula, though only *P. bonelli* and *P. canestrinii* in the same catchment (River Mirna). In the Skadar Lake basin, *P. montenegrensis* and *K. montenegrina* live in sympatry. Finally, in the River Cetina, *K. caucasica* and *P. canestrinii* were found. Further ecological studies are necessary to reveal the extent of range of the species and ecological overlaps between them. In most basins, two euryhaline and one or two freshwater species occur. Only freshwater species have up to now been found just in the Skadar Lake basin, whereas in the River Cetina only euryhaline species have been recorded. Furthermore, the endemism of strictly freshwater species, occurring (with the exception of *P. bonelli)* always in only one river basin, seems to be an interesting phenomenon. In general, evolution and dispersion of freshwater fishes are closely related to paleogeography and especially to the history of basin connections as a consequence of the geological development of landscapes (Bianco 1990; Bermingham & Martin, 1998). The differentiation within the freshwater gobies from the Western Balkan Adriatic drainage basin may have well resulted from the late Miocene to Quaternary hydrographic events in the Adriatic basin (Bianco & Miller, 1990; Miller, 1990; Miller & Šanda, 2008). Marine regressions led to connections of the previously isolated river basins (Bianco, 1990). Marshy conditions must have promoted the extension of the euryhaline lagoonal fauna along the coastline of the much shorter Adriatic basin, where the Meso-Adriatic Depression (Fossa Meso-Adriatica) remained a flooded basin that may have facilitated the dispersal of euryhaline fishes between catchments that are now separate (Bianco & Miller, 1990). Subsequent rise of the sea level, as a strong vicariant event, might have served to isolate estuarine and freshwater populations of freshwater gobies. To understand the biogeography and phylogenetic relationships of the freshwater gobies from the Adriatic drainage basin of the Western Balkans, further investigation is necessary, which would include incorporation of molecular techniques.

Finally, a good knowledge of the biology and ecology of the freshwater gobies of the Western Balkan Adriatic drainage basin, together with the identification of their population status and possible threats, will allow for efficient preparation of adequate national action plans.

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SLADKOVODNI GLAVAČI V JADRANSKEM POVODJU ZAHODNEGA BALKANA

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POVZETEK

Naše znanje o zahodnobalkanskih sladkovodnih glavačih Jadranskega povodja je še vedno preskromno, da bi lahko poskrbeli za njihovo ustrezno in učinkovito zaščito. V članku avtorja navajata nove podatke o geografski in ekološki razširjenosti sladkovodnih glavačev v Jadranskem povodju zahodnega Balkana. Za vrste Knipowitschia caucasica, Padogobius bonelli *in* Pomatoschistus canestrinii *sta ugotovila, da je njihov areal precej večji v obravnavanem območju od areala, znanega doslej. Prvič je bilo zabeleženo pojavljanje vrst* Knipowitschia radovici *in* Knipowitschia croatica *v povodju reke Neretve v Bosni in Hercegovini. Najdba* K. radovici *pa je doslej drugi znani zapis te vrste. Poročilo o pojavljanju glavača* Pomatoschistus montenegrensis *v Albaniji je prvo o tej vrsti iz tega dela Balkana.*

Ključne besede: Gobiidae, geografska razširjenost, ekološka razširjenost, Jadransko povodje, zahodni Balkan

REFERENCES

Bermingham, E. & A. P. Martin (1998): Comparative mtDNA phylogeography of neotropical freshwater fishes: Testing shared history to infer the evolutionary landscape of lower Central America. Mol. Ecol., 7, 499–517.

Bianco, P. G. (1990): Potential role of the paleohistory of the Mediterranean and Paratethys basins on the early dispersal of Mediterranean freshwater fishes. Ichthyol. Explor. Freshw., 1, 167–184.

Bianco, P. G. & P. J. Miller (1990): Yugoslav and other records of the Italian freshwater goby, *Padogobius martensii*, and a character polarization in gobioid fishes. J. Nat. Hist., 24, 1289–1302.

Dulčić, J., P. Tutman, B. Glamuzina, B. Skaramuca & H. Ahnelt (2008): Endemic gobies (Gobiidae) of the Hutovo blato wetland (Neretva River basin, Bosnia and Herzegovina) and their conservation status. In: Skaramuca, B. & J. Dulčić (eds.): Zbornik radova znanstveno-naučnog skupa Ugrožene i endemske vrste riba u slivovima rijeka Neretve, Trebišnjice i Morače (Park prirode Hutovo blato, 14.–15. prosinca 2007). Sveučilište u Dubrovniku, The EastWest Institute, Dubrovnik, pp. 61–66.

Economidis, P. S. & P. J. Miller (1990): Systematics of freshwater gobies from Greece. J. Zool. Lond., 221, 125–170.

Glamuzina, B., J. Dulčić, E. Hasković, A. Ivanc, S. Mandić, D. Mrdak & B. Skaramuca (2008): Stanje ihtiofaune u slivovima rijeka Neretve, Trebišnjice i Morače tijekom ljetnih meseci 2007. godine. In: Skaramuca, B. & J. Dulčić (eds.): Zbornik radova znanstveno-naučnog skupa Ugrožene i endemske vrste riba u slivovima rijeka Neretve, Trebišnjice i Morače (Park prirode Hutovo blato, 14.–15. prosinca 2007). Sveučilište u Dubrovniku, The EastWest Institute, Dubrovnik, pp. 21–41.

Ivanović, B. M. (1973): Ichthyofauna of Skadar Lake. Montenegrin Institute of Biological and Medical Research, Podgorica Biological Station, Podgorica, 146 p.

Kottelat, M. & J. Freyhof (2007): Handbook of European freshwater fishes. Kottelat, Cornol and Freyhof, Berlin, 646 p.

Kovačić, M. (2005a): A new species of *Knipowitschia* (Gobiidae) from Dalmatia, Croatia. Cybium, 29(3), 275–280.

Kovačić, M. (2005b): Morphological variability of *Pomatoschistus canestrinii* (Gobiidae), with the reduction of squamation and head canals. Cybium, 29(4), 373–379.

Kovačić, M. & A. Pallaoro (2003): Is *Knipowitschia caucasica*-like form from the Adriatic Sea a new Goby species? Evidence from a morphological approach in the Eastern Adriatic Sea. Cybium, 27, 81–164.

Kovačić, M. & R. Šanda (2007): A new species of Knipowitschia (Perciformes: Gobiidae) from southern Montenegro. J. Natl. Mus. (Prague), Nat. Hist. Ser., 176(5), 81–89.

Leiner, S. & M. Povž (1993): Sladkovodne ribe (Pisces) Istrskega polotoka. Ichthyos, 12, 23–34.

Leiner, S. & M. Povž (1994): The freshwater fishes of Istrian Peninsula. Period. Biol., 96(4), 431–434.

Leiner, S., M. Povž & M. Mrakovčić (1995): Freshwater fish in Istrian Peninsula. Annales, Ser. Hist. Nat., 5(1), 215–222.

Marić, D. (1995): Endemic fish species of Montenegro. Biol. Conserv., 72(2), 187–194.

McKay, S. I. & P. J. Miller (1997): The affinities of European sand gobies (Teleostei: Gobiidae). J. Nat. Hist., 31, 1457–1482.

Miller, P. J. (1972): Gobiid fishes of the Caspian genus *Knipowitschia* from the Adriatic Sea. J. Mar. Biol. Ass. U.K., 52, 145–160.

Miller, P. J. (1988): New species of *Corcyrogobius, Thorogobius* and *Wheelerigobius* from West Africa (Teleostei: Gobiidae). J. Nat. Hist., 22, 1245–1262.

Miller, P. J. (1990): The endurance of endemism: the Mediterranean freshwater gobies and their prospects fir survival. J. Fish Biol., 37 (Suppl. A), 145–156.

Miller, P. J. (ed.) (2003): The Freshwater Fishes of Europe, Vol. 8/I. Aula-Verlag, Wiebelsheim, 416 p.

Miller, P. J. (ed.) (2004): The Freshwater Fishes of Europe. Vol. 8/II. Aula-Verlag, Wiebelsheim, 478 pp.

Miller, P. J. (2009): A West Balkanian freshwater gobiid fish, *Knipowitschia mrakovcici* sp. nov. (Teleostei: Gobiidae). J. Fish Biol., 74(7), 1499–1507.

Miller, P. J. & R. Šanda (2008): A new West Balkanian sand-goby (Teleostei: Gobiidae). J. Fish Biol., 72(1), 259–270.

Miller, P. J., E. D. Vasiľeva & A. N. Economou (2004): *Knipowitschia caucasica* (Berg, 1916). In: Miller, P. J. (ed.): The Freshwater Fishes of Europe. Vol. 8/II. Aula – Verlag, Wiesbaden, pp. 343–364.

Mrakovčić, M., D. Schneider & M. Kerovec (1994): Freshwater gobies of Croatia. Period. Biol., 96, 441–443.

Mrakovčić, M., M. Kerovec, S. Mišetić & D. Schneider (1996): Description of *Knipowitschia punctatissima croatica*, (Pisces: Gobiidae), a new freshwater goby from Dalmatia, Croatia. In: Kirchhofer, A. & D. Hefti (eds.): Conservation of Endangered Freshwater Fish in Europe. Birkhauser Verlag, Basel, pp. 311–319.

Mrakovčić, M., A. Brigić, I. Buj, M. Ćaleta, P. Mustafić & D. Zanella (2006): Crvena knjiga slatkovodnih riba Hrvatske. Ministarstvo kulture, Državni zavod za zaštitu prirode, Zagreb.

Sanzo, L. (1911): Distribuzione delle papille cutanee (organi ciatiforme) e suo valore sistematico nei Gobi. Mitt. Zool. Stat. Neapel, 20, 249–328.

Vinciguerra, D. (1933): Pesci di Albania raccolti dal Dr. Pietro Parenzan nel 1930. Ann. Mus. Civ. Stor. Nat. Genova, 56, 303–310.

Vuković, T. (1977): Ribe Bosne i Hercegovine. Igkro Svetlost, Sarajevo.

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ON THE CAPTURE OF A LARGE BASKING SHARK *CETORHINUS MAXIMUS* (CHONDRICHTHYES: CETORHINIDAE) IN THE BAY OF EDREMIT (NORTHEASTERN AEGEAN SEA)

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ABSTRACT

On January 2, 2009, an adult male basking shark, Cetorhinus maximus *(Gunnerus, 1765), was accidentally caught in a stationary net in the waters some 2 nautical miles off Küçükkuyu (Bay of Edremit, NE Aegean Sea) by local fishermen. Total length of the basking shark was ca. 1,000 cm and weighing approximately 2,000 kg. Basking sharks occur along the Aegean and Mediterranean coastal waters of Turkey throughout the year with a peak in late spring and early autumn. The specimen under consideration is the largest well-documented basking shark recorded in the Mediterranean to date. Due to the inshore occurrence of* C. maximus *in Turkish waters, coastal artisanal fishermen should be informed about the conservation status of the basking sharks, and should also be forced to release the entangled basking sharks.*

Key words: basking shark, *Cetorhinus maximus*, Aegean Sea, coastal occurrence, coastal fishery, conservation

SULLA CATTURA DI UN GRANDE SQUALO ELEFANTE *CETORHINUS MAXIMUS* (CHONDRICHTHYES: CETORHINIDAE) NELLA BAIA DI EDREMIT (MAR EGEO NORD-ORIENTALE)

SINTESI

Il 2 gennaio 2009 è stato accidentalmente catturato con una rete da posta un maschio adulto di squalo elefante, Cetorhinus maximus *(Gunnerus, 1765), 2 miglia al largo di Küçükkuyu (Bay of Edremit, NE Aegean Sea) da pescatori del luogo. La lunghezza totale dell'esemplare era di circa 1000 cm per un peso di circa 2000 kg. Gli squali elefante sono presenti nelle acque costiere egee e mediterranee della Turchia durante tutto l'anno con picchi nella tarda primavera e nel primo autunno. L'animale considerato è lo squalo elefante più grande mai documentato nel Mediterraneo fino ad oggi. Vista la presenza in acque costiere turche di* C. maximus*, gli autori ritengono che i pescatori artigianali debbano venir informati in merito allo stato di conservazione della specie, e debbano venir obbligati a rilasciare gli esemplari di squalo elefante catturati.*

Parole chiave: squalo elefante, *Cetorhinus maximus*, Mar Egeo, avvistamento costiero, pesca costiera, conservazione

INTRODUCTION

Basking shark, *Cetorhinus maximus* (Gunnerus, 1765), occurs in warm and temperate waters of both Atlantic and Pacific Oceans, but is apparently absent in the Indian Ocean (Compagno, 1984). This giant plankton feeding shark is the largest fish living in the Mediterranean waters (Serena, 2005), and has been credited as reaching a maximum total length of 15.2 m (Compagno, 1984). Presence of the basking shark in the western Mediterranean has been accounted by numerous researches (*e.g.* Barrul *et al*. (1999) from Catalan waters; Capapé (1977) from Toulon waters; Capapé *et al*. (2003) from Maghrebin coastal waters; Lipej *et al*. (2000, 2004) from the Adriatic Sea). Despite its presence in the Aegean (Papaconstantinou, 1988; Kabasakal & Kabasakal, 2004) and Levant Seas (Ben-Tuvia, 1971; Kıdeyş, 1997; Kabasakal, 2002, 2004; Golani *et al*., 2006), it is considered a rare shark in the eastern Mediterranean (Serena, 2005).

In Turkish waters, basking shark is considered to be a relatively rare and occasional species (Akşıray, 1987; Fricke *et al*., 2007). According to Fricke *et al*. (2007), records of *C. maximus* in Turkish waters are mostly reported from around the Mersin coast.

On January 2, 2009, a male basking shark was entangled in stationary nets set close to the shore off Küçükkuyu in the Bay of Edremit. The aim of the present article is to give information on this accidentally caught specimen, as well as to discuss the present status of the basking shark in Turkish waters.

MATERIAL AND METHODS

The basking shark was measured and photographed after the fishing boat docked in the Küçükkuyu harbour. Total length (TOT in Compagno, 1984) was measured with a measuring tape to the closest cm. Unfortunately the specimen was immediately eviscerated and sold at the fish market in Küçükkuyu (Bay of Edremit, NE Aegean Sea). Photographs and the page of the newspaper presenting the capture of the caught specimen are kept in the archives of the Ichthyological Research Society (IRS).

Fig. 1: Page of the newspaper presenting the accidental catch of a basking shark, *Cetorhinus maximus* ***(Gunnerus, 1765), off the coast of Küçükkuyu (Bay of Edremit, NE Aegean Sea). Translation of the subtitle reads: "Surprising 10 metre shark from Dardanelles!"***

Sl. 1: Stran iz časnika, v katerem so poročali o morskem psu orjaku *Cetorhinus maximus* ***(Gunnerus, 1765), naključno ujetem v bližini kraja Küçükkuyu (Edremitski zaliv, SV Egejsko morje). Prevod podnaslova se dobesedno glasi: "Presenetljivi desetmetrski morski pes iz Dardanel!"***

RESULTS AND DISCUSSION

On January 2, 2009, an adult male basking shark (Fig. 1) was accidentally caught in a stationary net in the waters some 2 nautical miles off Küçükkuyu by local fishermen (Fig. 2). Total length of the basking shark was ca. 1,000 cm, while its weight was approximately 2,000 kg. After a short display in the harbour, the shark was eviscerated and purchased by a local fishmonger who intended to export it.

According to the available literature dealing with the elasmobranchs of Turkey, at least 5 basking sharks were recorded in Turkish waters to date (Kıdeyş, 1997; Kabasakal, 2002, 2004; Kabasakal & Kabasakal, 2004). Four of these records were from the Mediterranean coast of Turkey (Kabasakal, 2004), and only one from the Bay of Saros (northeastern Aegean Sea off the Anatolian coast; Kabasakal & Kabasakal, 2004).

On April 18, 1987, a basking shark was accidentally captured by stationary nets set very close to the shore of Kemer in the Bay of Antalya (Kabasakal, 2004). The specimen's total length measured by the fishermen was 4 m, its weight ca. 800 kg. The girth of the specimen was 140 cm. It was pulled on to the beach by a tractor and displayed to the public for a few days. In May 1995, coastal fishermen captured two basking sharks near Erdemli in the Bay of Mersin (Kıdeyş, 1997). One of these basking sharks was 4.7 m long, while sex of the two specimens remains unknown. In August and September of the ensuing year, a small school of basking sharks was sighted in the same area while feeding on the bloom of ctenophoran *Pleurobrachia pileus* (Kıdeyş, 1997). On May 16, 1997, a basking shark of ca. 800 cm TL was sighted by a swordfish harpooner some 5 nautical miles off the southern coast of Gökçeada, NE Aegean Sea (Kabasakal & Kabasakal, 2004). This sighting was the most recent record of *C. maximus* from Turkish coastal waters of the NE Aegean Sea. In December 2001, another basking shark was also captured by means of a stationary bonito net, set only 100 m off the shore in the Bay of Antalya (Kabasakal, 2002). Total length of this female (believed to be a sub-adult in view of its size) was 6 m (Kabasakal, 2002). Unfortunately, this basking shark was immediately eviscerated and sold, too.

Fig. 2: Map indicating the approximate locality of capture (black circle) of the basking shark.
Sl. 2: Zemljevid s približno lokacijo (črni krogec), kjer se je v mrežo zapletel morski pes orjak.

The present record of *C. maximus* in the Bay of Edremit, as well as the records by Papaconstantinou (1988) and Kabasakal & Kabasakal (2004) indicate that the distribution range of the basking shark extends to the northern Aegean Sea; it is still not clear, however, whether the basking shark is an occasional species in the area or occurs here seasonally.

Barrul *et al*. (1999) reported on 20 basking sharks from Catalan waters (western Mediterranean), whose total lengths ranged from 250 to 800 cm. Total lengths of 21 basking sharks caught in Maghrebin coastal waters varied between 270 and 735 cm (Capapé *et al*., 2003). According to Lipej *et al*. (2004), Serena (2005) and Golani *et al*. (2006), total length of *C. maximus* can reach 1,000 cm in general. Tortonese (1956) and Compagno (1984) stated even greater sizes, 1,300 and 1,520 cm, respectively. Hence, it is possible to suggest that the present specimen (ca. 1,000 cm TL) is one of the largest basking sharks ever captured in the Mediterranean Sea.

Although basking sharks are non-target species in the Mediterranean Sea, they are accidentally caught by numerous fishing gears (Soldo, 2003). Thus, they are evidently vulnerable to bycatch. Accidental capture of basking sharks by coastal fishermen have been reported from several regions in the Mediterranean Sea by Ben-Tuvia (1971), Kıdeyş (1997), Lipej *et al*. (2000), Kabasakal (2002) and Capapé *et al*. (2003). One of the basking sharks (267 cm of TL) reported by Ben-Tuvia (1971) was entangled in gill-nets at a depth of 3 m near Akko (eastern Mediterranean) on January 11, 1965, while yet another individual (259 cm of TL) was caught in the very same area on March 7, 1965. Capapé *et al*. (2003) reported that all the specimens from Maghrebin coastal waters were captured by pelagic fishing gear at depths of max. 30 m. A 6 metre long (TL) sub-adult female was entangled in a stationary bonito net, set only 100 metres off the shore in the Bay of Antalya (Kabasakal, 2002). Two basking sharks recorded by Kıdeyş (1997) off Erdemli coast, Bay of Mersin, were entangled in stationary nets, set close to the shore. Lipej *et al*. (2000) reported on two juvenile basking sharks (249 and 299 cm TL, and weighing 70 and 120 kg, respectively), which were accidentally caught in stationary nets in the waters off Piran. The present specimen, too, was a victim of a gill-net set close (ca. 2 nautical miles) to the shore. Basking shark is a rather rare but constantly present species in the eastern Adriatic Sea (Soldo *et al*., 2008). Over the 2000–2002 period, their occurrence in this area highly increased owing to the abundance of copepods, especially *Calanus helgolandicus* (Soldo *et al*., 2008).

According to Francis & Duffy (2002), inshore records of *C. maximus* from miscellaneous sources peaked in spring-summer, with few winter records. Just occasionally, an isolated individual – like the present basking shark or the Antalya specimen caught in December 2001 – is caught during the winter months (Steel, 1985). The basking shark accounted by Kabasakal (2002) was also accidentally caught during the winter in a stationary bonito net set in coastal waters in the Bay of Antalya. Migrations of basking sharks in the seas of Turkey, particularly in coastal waters where intensive fishery by means of several kinds of stationary nets is carried out, should be determined in detail in order to reduce the possible impacts of this vulnerable shark by-catch.

Gill-netting is a popular technique of small-scale fishery in Turkish coastal waters and operated throughout the year. Therefore, coastal fishermen should be informed about the basking shark's status, about the ban on trading endangered marine animals, and encouraged to release the entangled specimens. Budgeting of conservation of endangered marine animals is an important obstacle, preventing fishermen to release the entangled specimens. Generally, fishermen claim that they have to land and sell large sharks in order to compensate for the cost of damaged fishing gear. Thus, in addition to including the basking shark on the list of endangered marine animals of Turkish seas, the government should set a plan for the compensation of damaged fishing gear in the event of the sharks' entanglement. Basking shark is listed in the Act 37/2 – Endangered Species of the Seas of Turkey; however, this regulation seems ineffective for the protection of this gentle giant, if fishermen have no intention of releasing the entangled specimens. Available studies on the distribution of basking sharks in Turkish waters indicate that the species occurs along the Aegean and Mediterranean coastal waters of Turkey throughout the year with a peak in late spring and early autumn. This annual occurrence necessitates revising the terms of coastal year-round artisanal fishery.

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O MORSKEM PSU ORJAKU *CETORHINUS MAXIMUS* (CHONDRICHTHYES: CETORHINIDAE), UJETEM V EDREMITSKEM ZALIVU (SEVEROVZHODNO EGEJSKO MORJE)

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POVZETEK

Dne 2. januarja 2009 so lokalni ribiči v mreži, ki so jo nastavili kaki dve morski milji od Küçükkuyua (Edremitski zaliv, SV Egejsko morje), našli po nesreči ujetega odraslega samca morskega psa orjaka Cetorhinus maximus *(Gunnerus, 1765). Njegova celotna dolžina je merila cca 1000 cm, teža pa približno dve toni. Ta vrsta morskih psov se pojavlja v obalnih vodah Egejskega morja in Turčije vse leto, z vrhuncem v poznem spomladanskem in zgodnjem jesenskem času. Obravnavani morski pes orjak je največji dobro dokumentirani primerek te vrste, kar jih je bilo kdaj zabeleženih v Sredozemskem morju. Zaradi pojavljanja morskih psov orjakov v turških obalnih vodah je po avtorjevem mnenju treba lokalne ribiče, ki lovijo na tradicionalni način z manjšimi mrežami in čolni, dodobra seznaniti z naravovarstvenim statusom morskega psa orjaka in jih hkrati prisiliti, da spustijo na prostost v mreže zapletene orjake.*

Ključne besede: morski pes orjak, *Cetorhinus maximus*, Egejsko morje, pojavljanje v obrežnih vodah, obalno ribištvo, naravovarstvo

REFERENCES

Akşıray, F. (1987): Türkiye Deniz Balıkları ve Tayin Anahtarı. 2nd Edition. Publications of İstanbul University, İstanbul, no. 3490, 811 p.

Barrull, J., I. Mate & M. Bueno (1999): Observaciones de tiburones (Chondrichthyes Euselachii) en aguas de Cataluña (Mediterraneo No), con algunos aspectos generales de su ecología. Sci. Gerund., 24, 127–151.

Ben-Tuvia, A. (1971): Revised list of the Mediterranean fishes of Israel. Isr. J. Zool., 20, 1–39.

Capapé, C. (1977): Liste commentée des sélachiens de la région de Toulon (de la ciotat à Saint-Tropez). Bull. Mus. Hist. Nat. Marseille, 37, 5–9.

Capapé, C., F. Hemida, J. Bensaci, B. Saïdi & M. N. Bradaï (2003): Records of basking sharks, *Cetorhinus maximus* (Gunnerus, 1765) (Chondrichthyes: Cetorhinidae) off the Maghrebine shore (southern Mediterranean): a survey. Annales, Ser. Hist. Nat., 13(1), 13–18.

Compagno, L. J. V. (1984): FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of sharks species known to date. Part 1. Hexanchiformes to Lamniformes. FAO Fish. Synop., 4, 1–249.

Francis, M. P. & C. Duffy (2002): Distribution, seasonal abundance and bycatch of basking sharks *(Cetorhinus maximus)* in New Zealand, with observations on their winter habitat. Mar. Biol., 140, 831–842.

Fricke, R., M. Bilecenoğlu & H. M. Sarı (2007): Annotated checlist of fish and lamprey species (Gnathostomata and Petromyzontomorphi) of Turkey, including a Red List of threatened and declining species. Stuttg. Beitr. Natkd. A. Biol., 706, 1–169.

Golani, D., B. Öztürk & N. Başusta, (2006): Fishes of the eastern Mediterranean. Turkish Marine Research Foundation (Türk Deniz Araştırmaları Vakfı) TÜDAV, İstanbul, 260 p.

Kabasakal, H. (2002): Capture of a female basking shark, *Cetorhinus maximus* (Gunnerus, 1765), from southern Turkey. Annales, Ser. Hist. Nat., 12(1), 31–34.

Kabasakal, H. (2004): *Cetorhinus maximus* (Gunnerus, 1765) (Lamniformes, Cetorhinidae) in the Gulf of Antalya in 1987: A summary of the previous records of the species from Turkish coastal waters in the Mediterranean. Annales, Ser. Hist. Nat., 14(1), 29–34.

Kabasakal, H. & E. Kabasakal (2004): Sharks captured by commercial fishing vessels off the coast of Turkey in the northern Aegean Sea. Annales, Ser. Hist. Nat., 14(2), 171–180.

Kıdeyş, A. E. (1997): Occurrence of the basking shark, *Cetorhinus maximus*, in the northern Levantine, the eastern Mediterranean. The International Mediterranean Fisheries Congress. Book of Abstracts. University of Ege, İzmir, pp. 120.

Lipej, L., T. Makovec, M. Orlando & V. Žiža (2000): Occurrence of the basking shark, *Cetorhinus maximus* (Günnerus, 1765), in the waters off Piran (Gulf of Trieste, Northern Adriatic). Annales, Ser. Nist. Nat., 10(2), 211–216.

Lipej, L., A. De Maddalena & A. Soldo (2004): Sharks of the Adriatic Sea. Knjižnica Annales Majora, Koper, 253 p.

Papaconstantinou, C. (1988): Check-list of marine fishes of Greece. Fauna Graeciae 4. National Center for Marine Research, Hellenic Zoological Society, Athens, 257 p.

Serena, F. (2005): Field identification guide to the sharks and rays of the Mediterranean and Black Sea. FAO Species Identification Guide for Fishery Purposes. FAO, Rome, 97 p.

Soldo, A. (2003): Status of sharks in the Mediterranean. Annales, Ser. Hist. Nat., 13(2), 191–200.

Soldo, A., D. Lučić & I. Jardas. (2008): Basking shark *(Cetorhinus maximus)* occurrence in relation to zooplankton abundance in the eastern Adriatic Sea. Cybium, 32(2), 103–109.

Steel, R. (1985): Sharks of the World. Facts on File Publications, New York, 192 p.

Tortonese, E. (1956): Fauna d'Italia. Vol. II. Leptocardia, Ciclostomata, Selachii. Calderini, Bologna, 334 p.

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BREEDING OF THE MEDITERRANEAN GULL *LARUS MELANOCEPHALUS* IN SLOVENIA

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ABSTRACT

Breeding of the Mediterranean Gull Larus melanocephalus *has been confirmed for the fist time in Slovenia. In a mixed Black-headed Gull* Larus ridibundus *(160 breeding pairs) and Common Tern* Sterna hirundo *colony (45 breeding pairs), a nest of Mediterranean Gull with four warm eggs was found on 23rd May 2006. Breeding was successful – an adult Mediterranean Gull was observed feeding its young close to the colony on 1st July 2006. Breeding in Slovenia was expected, as the species' breeding range is in expansion. From 1984 until the first breeding, it was recorded 17 times during the breeding period in NE Slovenia. An adult Mediterranean Gull was observed for the first time in a colony in 1997, but until 2001 no breeding attempts were observed. Breeding attempts in the colony were recorded in 2001 and 2005. The mixed colony on Lake Ptuj (SE Slovenia, Drava River) is located on two artificial islets (830 and 200 m² surface area) and two concrete power-line pedestals. The islets are overgrown with herbal vegetation. Based on observations of adults and colony visits, two pairs of Mediterranean Gull were breeding in the colony in 2007, one pair in 2008, and at least one pair in 2009. After breeding in four successive years, we treat the Mediterranean Gull as a regular breeder in Slovenia.*

Key words: Mediterranean Gull, *Larus melanocephalus*, breeding, colonization, Slovenia

RIPRODUZIONE DEL GABBIANO CORALLINO *LARUS MELANOCEPHALUS* IN SLOVENIA

SINTESI

La riproduzione del gabbiano corallino Larus melanocephalus *è stata confermata per la prima volta in Slovenia. In una colonia mista di gabbiano comune* Larus ridibundus *(160 coppie nidificanti) e sterna commune* Sterna hirundo *(45 coppie nidificanti), il 23 maggio 2006 è stato trovato un nido di gabbiano corallino con quattro uova calde. L'accoppiamento ha avuto successo ed un adulto di gabbiano corallino è stato osservato mentre nutriva la prole, in prossimità della colonia, il 1° luglio 2006. La riproduzione di tale specie in Slovenia era un fatto da aspettarsi, in quanto il range riproduttivo della specie è in espansione. Dal 1984 fino al 2006 la specie è stata segnalata 17 volte durante il periodo riproduttivo nel NE della Slovenia. Un adulto di gabbiano corallino è stato osservato per la prima volta in una colonia nel 1997, ma fino al 2001 non sono stati registrati tentativi di riproduzione (segnalati poi nelle colonie fra il 2001 ed il 2005). La colonia mista del lago di Ptuj (Slovenia SE, fiume Drava) è situata su due isole artificiali (830 e 200 m² di superficie) e due piedestalli di calcestruzzo. Due coppie di gabbiano corallino sono state avvistate mentre nidificavano nella colonia nel 2007, una coppia nel 2008, ed almeno una coppia nel 2009. Dopo quattro anni successivi di tali avvistamenti, gli autori considerano il gabbiano corallino quale specie regolarmente nidificante in Slovenia.*

Parole chiave: gabbiano corallino, *Larus melanocephalus*, riproduzione, colonizzazione, Slovenia

INTRODUCTION

The greater part of the Mediterranean Gull *Larus melanocephalus* breeding range is confined to the western Palearctic. In the 1940s and 1950s, it bred almost exclusively in south-western Europe, on the shores of Black and Azov Sea. In the 1950s and 1960s, it began spreading its breeding range into Middle and Western Europe, where it nowadays breeds in most of the countries. The largest populations in that part of Europe are in France (2300 pairs), Italy (up to 3000 pairs), Belgium (1450 pairs) and in the Netherlands (850 pairs). All of them increased after 1990 (Bekhuis *et al.*, 1997; Glutz von Blotzheim & Bauer, 1999; BirdLife International, 2004; Brichetti & Fracasso, 2006).

Due to breeding range expansion, enlargement of disjunct populations and long-term stable central population in Ukrainian part of the Black Sea, counting up to 300,000 pairs, the Mediterranean Gull has been recently evaluated as an expanding species (BirdLife International, 2004).

The Mediterranean Gulls select small islands with short vegetation as breeding sites. In Middle and Western Europe, they usually form mixed colonies with Black-headed Gulls *L. ridibundus* (Glutz von Blotzheim & Bauer, 1999). Such colonies can be found in countries bordering Slovenia, too – Neusiedler See in Austria (Laber, 2000) and Kis Balaton in Hungary (Varga *et al.*, 1996). In Italy, it breeds in larger-sized Adriatic coastal wetlands and saltpans where it forms dense mixed colonies with Black-headed and Yellow-legged Gulls *L. michahellis* and Common *Sterna hirundo* and Little Terns *Sternula albifrons* (Brichetti & Fracasso, 2006). So far, breeding has not been confirmed in Croatia (Kralj, 1997; Radović *et al.*, 2005). Continental populations of the Mediterranean Gull are smaller than those in coastal areas and rarely exceed several pairs (Bauer *et al.*, 2005).

In Slovenia, the species is regularly recorded on the coast during migration and the wintering period, and its numbers fluctuate from low during spring migration to the Eastern European breeding sites to high in late summer and autumn. An estimated 0.5–5.0% of the world population migrates over the Slovenian coast in late summer and autumn (Rubinič, 1995). Mediterranean Gull is a rare migratory species in the continental part of Slovenia – there are only two records from well-surveyed wetland sites in central Slovenia, one from Cerknica Lake (Kmecl & Rižner, 1993) and one from Ljubljansko barje (Tome *et al.*, 2005). The exceptions are few sites in the Drava river floodplain area. During the last two decades, Mediterranean Gull was most regularly observed on Lake Ptuj (own data).

The aim of this work is to give an overview of the past occurrence of Mediterranean Gull in the breeding season in continental Slovenia indicating species' colonisation, and to present data on its confirmed breeding.

MATERIAL AND METHODS

The study was conducted at Lake Ptuj on the Drava River in NE Slovenia. This is a large water reservoir for the channel-type power plant Formin that started operating in 1978. Surface of the lake is 4.2 km^2; the embankments of the lake are artificial (Šmon, 2000). The area

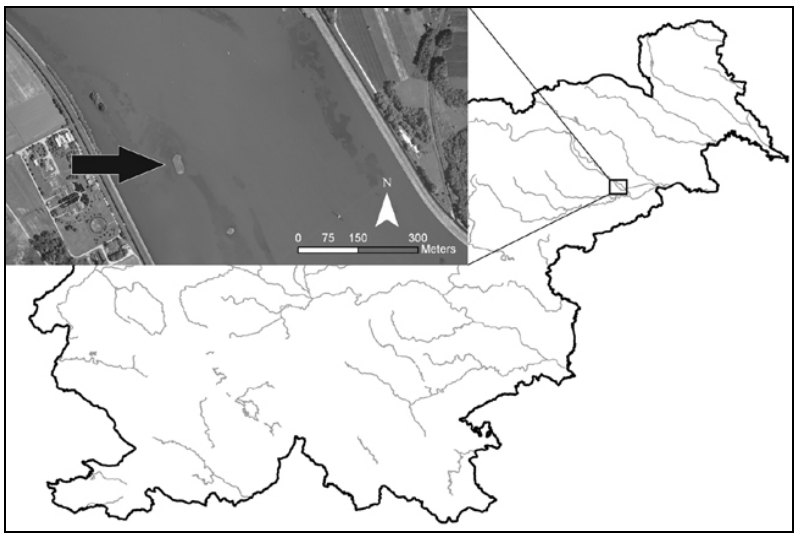

Fig. 1: Map of Slovenia with marked Lake Ptuj reservoir. Black arrow indicates the islet where Mediterranean Gull *Larus melanocephalus* ***was breeding. (Map source: DOF5, GURS)***
Sl. 1: Zemljevid Slovenije z označenim Ptujskim jezerom. Črna puščica kaže otok, kjer je gnezdil črnoglavi galeb *Larus melanocephalus****. (Vir: DOF5, GURS)***

Fig. 2: Breeding habitat of the Mediterranean Gull *Larus melanocephalus* ***at Lake Ptuj, 23rd May 2006. (Photo: D. Denac)***
Sl. 2: Gnezditveni habitat črnoglavega galeba *Larus melanocephalus* ***na Ptujskem jezeru, 23. 5. 2006. (Foto: D. Denac)***

(46°24′27′′ N, 15°53′05′′ E) is situated in the subpannonical zoogeographic region of Slovenia (Mršić, 1997) and is part of the Special Protected Area (SPA) SI5000011 Drava (Uradni list RS, 2004). This SPA is particularly significant as a wintering site for waterbirds at the national and international levels. It holds nationally important breeding populations of the Kingfisher *Alcedo atthis* and Common Tern (Štumberger, 2000; Božič, 2003).

There are three artificial islets on the lake (Fig. 1). Surface of the first islet is 790 m^2, 200 m^2 of the second, and 830 $m^2$of the third. Their distances from the bank of the lake are 50, 200 and 155 m, respectively. The first two islets were made of gravel and created before the lake was filled with water. The third was created in winter 2004/05 using lake sediments (Fig. 2). The first islet is currently overgrown by trees, whereas the vegetation of the other two is regularly mown by members of DOPPS-BirdLife Slovenia, thus maintaining the clear breeding site of the gull and tern colony.

Common Terns and Black-headed Gulls breed on mown islets and on two concrete power-line pedestals (Geister, 1995; Bračko, 1999; Denac, 2004). During the regular annual monitoring of the breeding colony in 2006, 2007 and 2009, the largest (third) islet was visited and the number of nests and clutch sizes counted. Clutches were determined using an identification key (Harrison, 1975). Recommendations for minimal disturbance of breeding birds were followed during our visit (Wagener, 1998). Due to the very lush vegetation in 2007, and to avoid any potential damage on clutches and chicks, it was not possible to thoroughly check the colony ground and count all the nests during the colony visit. In 2008, the monitoring was conducted by counting breeding birds with telescope from the lake embankment.

For an overview of past occurrence of the Mediterranean Gull in the breeding season in continental Slovenia, published and unpublished data were included, but not the observations of the breeding Mediterranean Gulls in the colony.

RESULTS

Twenty nine (29) breeding season records are known for the NE part of Slovenia from 1984 onwards, with 17 of them made before the first confirmed breeding in 2006. In 1997, a Mediterranean Gull in its second-summer plumage was observed for the first time on Lake Ptuj in a colony of Black-headed Gulls, but no breeding activities were recorded (Tab. 1). The first territorial Mediterranean Gull was observed in a colony of Black-headed Gulls on Lake Ptuj in 2001. It was defending its territory and chasing away Black-headed Gulls (Smole, 2001). Similar behaviour was observed in the same colony in 2005, when an adult Mediterranean Gull courted a Black-headed Gull (Denac & Smole, 2005) and presumably bred in a mixed pair. The majority of birds recorded at Medvedce reservoir in the 2005-2008 period and a bird recorded in 2007 at Kungota pri Ptuju were presumably breeding individuals from Lake Ptuj (Bordjan & Božič, *submitted).*

Tab. 1: Occurrence of Mediterranean Gull** Larus melanocephalus **during the breeding season in continental Slovenia (author's data where source is empty). Legend: Ad – adult individual, 1st W – first-winter individual, 1st S – first-summer individual, 2nd S – second-summer individual.
Tab. 1: Pojavljanje črnoglavega galeba** Larus melanocephalus **v gnezditvenem obdobju v kontinentalni Sloveniji (kjer je pri viru prazno, so lastni podatki avtorjev). Legenda: Ad – odrasel osebek, 1st W – prvozimski osebek, 1st S – prvopoleten osebek, 2nd S – drugopoleten osebek.

Year	Place	No. individuals	Age	Status	Source	Observation dates
1984	Ledavsko lake	7	Ad	No breeding activity	Geister, 1984	09/07/84
1990	Hotinja vas	4	Ad	No breeding activity	Vogrin, 1990	11/04/90
1991	Ormož lake	1	1st W	No breeding activity		31/03/91
1994	Lake Ptuj	1	Ad	No breeding activity		08/04/94
1994	Turniški travniki (Lake Ptuj)	3	1 Ad, 2 2nd S	No breeding activity		19/04/94
1997	Lake Ptuj	1	2nd S	No breeding activity, present in a mixed Black-headed Gull and Common Tern colony		01/05/97 – 17/05/97
1997	Ormož lake, TSO waste water basins	2	2nd S	No breeding activity		05/05/97
2001	Medvedce reservoir	2	1 Ad, 1 2nd S	No breeding activity	Kerček, 2005	10/05/01
2001	Lake Ptuj	1	Ad	Territorial in a mixed Black-headed Gull and Common Tern colony	Smole, 2001	28/05/01 – 24/06/01
2003	Medvedce reservoir	1	Ad	No breeding activity	Kerček, 2005	04/04/03
2003	Medvedce reservoir	1	2nd S	No breeding activity	Kerček, 2005	26/06/03
2003	Medvedce reservoir	1	Unknown	No breeding activity	Kerček, 2005	29/06/03
2003	Medvedce reservoir	1	Unknown	No breeding activity	Kerček, 2005	10/07/03
2003	Medvedce reservoir	1	Ad	No breeding activity	D. Bordjan, *in lit.*	25/07/03
2004	Medvedce reservoir	1	2nd S	No breeding activity	Kerček, 2005	23/04/04
2005	Lake Ptuj	1	Ad	Breeding in a mixed pair with Black-headed Gull in the colony	Denac & Smole, 2005	14/05/01 – 29/05/05
2005	Medvedce reservoir	1	Ad	No breeding activity	Bordjan & Božič, *submitted*	25/07/05
2006	Medvedce reservoir	4	Ad	No breeding activity	Bordjan & Božič, *submitted*	19/06/06
2006	Medvedce reservoir	4	Ad	No breeding activity	Bordjan & Božič, *submitted*	06/07/06
2006	Medvedce reservoir	1	Ad	No breeding activity	Bordjan & Božič, *submitted*	12/07/06
2007	Medvedce reservoir	1	Ad	No breeding activity	Bordjan & Božič, *submitted*	18/03/07
2007	Kungota pri Ptuju	1	Ad	No breeding activity	M. Kerček, *in lit.*	02/06/07
2007	Medvedce reservoir	1	Ad	No breeding activity	Bordjan & Božič, *submitted*	06/06/07
2008	Medvedce reservoir	2	Ad	No breeding activity		24/06/08
2008	Medvedce reservoir	3	Ad	No breeding activity	D. Bordjan, *in lit.*	05/07/08
2008	Medvedce reservoir	1	1st S	No breeding activity	D. Bordjan, *in lit.*	06/07/08
2008	Medvedce reservoir	4	2 Ad, 2 1st S	No breeding activity	D. Bordjan, *in lit.*	12/07/08
2009	Ormož lake	1	Ad	No breeding activity	D. Bordjan, *in lit.*	15/03/09
2009	Ormož lake	2	Ad	No breeding activity		27/04/09 – 04/05/09

Tab. 2: Numbers of breeding Mediterranean Gulls *Larus melanocephalus* ***on Lake Ptuj in a mixed-species colony. Author's data supplemented with B. Štumberger*** *(in lit.).* ***Legend: * number of breeding pairs based on observations. Tab. 2: Števila gnezdečih črnoglavih galebov*** *Larus melanocephalus* ***na Ptujskem jezeru v mešani koloniji. Podatki avtorjev dopolnjeni z B. Štumberger*** *(in lit.).* ***Legenda: * število gnezdečih parov na osnovi opazovanj.***

Year	Place	No. breeding pairs (clutch size)	Description
2006	Lake Ptuj	1 (4)	Nest found (23/05/09) and fledged young observed (01/06/09)
2007	Lake Ptuj	2*	2 adults and 2 subadults flying above the colony (24/05/07 – 01/06/07), 11 juveniles on the lake (31/08/08 – 20/09/07)
2008	Lake Ptuj	1*	1 adult observed flying and foraging close to the colony (24/05/08)
2009	Lake Ptuj	1 (3) – 2*	Nest found (22/04/09) and several observations of up to 3 adults (23/03/09 – 09/05/09; the last observation included in the article)

Breeding of the Mediterranean Gull was for the first time confirmed at Lake Ptuj in the colony on the third islet in 2006. The mixed-species colony held 160 pairs of Black-headed Gull, 45 pairs of Common Tern and one (1) pair of Mediterranean Gull. The Mediterranean Gull clutch was identified when compared with numerous clutches of the Black-headed Gull. Mediterranean Gull eggs were considerably bigger and with distinctive pale ground coloration (Fig. 3). On the basis of the observations we infer that breeding took place in 2007 and 2008 as well. In 2009, breeding was confirmed again when a single Mediterranean Gull clutch was identified amidst 353 nests of Black-headed Gulls. Further observations in 2009 indicate the possibility of two breeding pairs (Tab. 2).

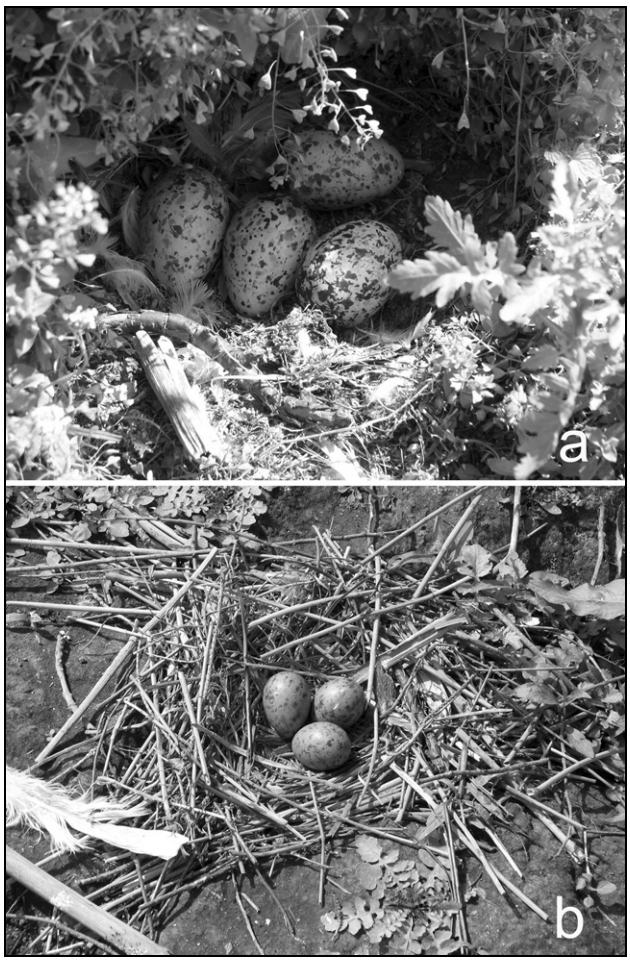

Fig. 3: Clutch of the Mediterranean Gull *Larus melanocephalus* ***(a), found on Lake Ptuj islet, 23rd May 2006, in comparison with (b) clutch of the Black-headed Gull*** *Larus ridibundus****. (Photo: D. Denac)***
Sl. 3: Leglo črnoglavega galeba *Larus melanocephalus* ***(a) na otoku na Ptujskem jezeru, 23. 5. 2006, v primerjavi z (b) leglom rečnega galeba*** *Larus ridibundus****. (Foto: D. Denac)***

DISCUSSION

In view of the recent range expansion, numerous observations in the past, at least one breeding attempt and suitable breeding places in the existing colonies of Black-headed Gulls and Common Terns, breeding of the Mediterranean Gull in Slovenia was expected. Compared with the majority of other countries in Central and Western Europe, the first confirmed breeding in Slovenia is rather late, *i.e.* some 30 years later than in neighbouring Austria and Italy (Laber, 2000; Brichetti & Fracasso, 2006). Partly, this can be a consequence of few Black-headed Gull colonies breeding regularly in Slovenia and a limited number of potentially suitable breeding sites. The pattern of colonization was similar as observed in many other European countries: individual breeding attempts and breeding of mixed pairs with Black-headed Gull were followed by confirmed breeding. Breeding was usually fairly irregular in the first years and often it took several years or even decades before colonization and larger colonies were established (Boschert, 1999; Chytil, 1999; Meininger & Flamant, 1999; Chytil & Macháček, 2000; Zielińska *et al.*, 2007). Breeding in a mixed pair with Black-headed or Common

Gull *L. canus* is otherwise known for this species (Deutsch & Buchheim, 1999; Glutz von Blotzheim & Bauer, 1999). After breeding for four successive years, we treat the Mediterranean Gull as a regular breeder. According to the data from other countries, regular breeding for several consecutive years occurred at only small part of breeding sites *(e.g.* Boschert, 1999). Monitoring of further development of the Mediterranean Gull breeding population at Lake Ptuj, particularly its size, remains a challenge. Although the majority of Mediterranean Gulls in continental areas breed in mixed-species colonies with Black-headed Gulls, the presence of the latter in high densities, as is the case on the islets at Lake Ptuj, could reduce the possibility of Mediterranean Gull population increase. Breeding season of the Black-headed Gull commences approximately one month earlier as that of the Mediterranean Gull (Bauer *et al.*, 2005) and the former can occupy the majority of suitable breeding places, as it was recorded in Vojvodina, Serbia (Gergelj *et al.*, 2004). A nest containing four eggs found in 2006 is quite unusual regarding the normal clutch size of 2-3 eggs. In Germany, only 5% of clutches contained four eggs. Presumably, such clutches originate from several females laying into a single nest (Bauer *et al.*, 2005).

The Mediterranean Gull is listed in Annex 1 of the Council Directive 79/409/EEC on the conservation of wild birds. Therefore, breeding records are important regarding conservation, too. For the time being, the Mediterranean Gull is not listed among species for which Special Protection Area (SPA) SI5000011 Drava (Uradni list RS, 2004) was designated. If numbers of the regularly breeding Mediterranean Gull eventually increase to at least five pairs, it will be necessary to review the existing official documents and list the Mediterranean Gull as a qualifying species of the SPA Drava in the scope of Natura 2000 network in Slovenia.

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GNEZDENJE ČRNOGLAVEGA GALEBA *LARUS MELANOCEPHALUS* V SLOVENIJI

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POVZETEK

Leta 2006 smo v Sloveniji prvič potrdili gnezditev črnoglavega galeba Larus melanocephalus. *Gnezdo s štirimi jajci je bilo najdeno 23. 5. 2006 v mešani koloniji rečnih galebov* Larus ridibundus *(160 gnezdečih parov) in navadnih čiger* Sterna hirundo *(45 gnezdečih parov) na otoku sredi Ptujskega jezera. Gnezditev je bila uspešna – v neposredni bližini kolonije smo 1. 7. 2006 opazovali speljanega mladiča, ki ga je hranil odrasel črnoglavi galeb. Gnezditev je bila pričakovana, saj je črnoglavi galeb vrsta v ekspanziji. V severovzhodni Sloveniji je bil črnoglavi galeb v gnezditvenem obdobju od leta 1984 do prve potrjene gnezditve opazovan 17-krat. V mešani koloniji na Ptujskem jezeru je bil prvič opazovan leta 1997, vendar do leta 2001 nismo registrirali poskusa gnezditve. Poskus gnezditve smo zabeležili leta 2001 in 2005. Mešana kolonija na Ptujskem jezeru gnezdi na dveh umetnih otokih (površine 830 in 200 m^2) in na dveh betonskih daljnovodnih podstavkih. Otočka prerašča zeliščna vegetacija. Na podlagi opazovanj in obiskov kolonij zaključujemo, da sta na Ptujskem jezeru leta 2007 gnezdila dva para, leta 2008 en par in leta 2009 najmanj en par črnoglavega galeba. To vrsto galeba zato prištevamo med redne gnezdilke v Sloveniji.*

Ključne besede: črnoglavi galeb, *Larus melanocephalus*, gnezdenje, kolonizacija, Slovenija

REFERENCES

Bauer, H. - G., E. Bezzel & W. Fiedler (eds.) (2005): Das Kompendium der Vögel Mitteleuropas. AULA Verlag, Wiebelsheim.

Bekhuis, J., P. Meininger & A. G. Rudenko (1997): *Larus melanocephalus* Mediterranean Gull. In: Hagemeier, E. J. M. & M. J. Blair (eds.): The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance. T & A D Poyser, London, pp. 324–325.

BirdLife International (2004): Birds in Europe: population estimates, trends and conservation status. BirdLife Conservation Series No. 12. BirdLife International, Cambridge.

Bordjan, D. & L. Božič (2009): Pregled pojavljanja vodnih ptic in ujed na vodnem zadrževalniku Medvedce (Dravsko polje, SV Slovenija) v obdobju 2002–2007. Acrocephalus. *(Submitted)*

Božič, L. (2003): Mednarodno pomembna območja za ptice v Sloveniji. 2. Predlogi posebnih zaščitenih območij (SPA) v Sloveniji. Monografija DOPPS št. 2, Ljubljana.

Boschert, M. (1999): Population trends and status of Mediterranean Gull *Larus melanocephalus* as a breeding bird in Germany. In: Meininger, P. L., W. Hoogendorn, R. Flamant & P. Raevel (eds.): Proc. of the 1st International Mediterranean Gull Meeting, 4–7 September 1998, Le Portel, Pas-de-Calais, France. EcoNum, Bailleul, pp. 43–46.

Bračko, F. (1999): Navadna čigra *Sterna hirundo*. Acrocephalus, 20(93), 60–61.

Brichetti, P. & G. Fracasso (2006): Ornitologia Italiana. Vol. 3. Stercorariidae-Caprimulgidae. Alberto Perdisa Ed., Bologna, 438 p.

Chytil, J. (1999): The present status of Mediterranean Gull *Larus melanocephalus* in the Czech Republic, with notes on Slovakia. In: Meininger, P. L., W. Hoogendorn, R. Flamant & P. Raevel (eds.): Proc. 1st International Mediterranean Gull Meeting, 4–7 September 1998, Le Portel, Pas-de-Calais, France. EcoNum, Bailleul, pp. 39–40.

Chytil, J. & P. Macháček (2000): Vývoj hnízdních populací rackovitých (Laridae) a rybákovitých (Sternidae) na nejjižnější Moravě. Sylvia, 36(2), 113–126.

Denac, D. (2004): Prehranjevalna dinamika in pojav znotrajvrstnega kleptoparazitizma v koloniji navadne čigre *Sterna hirundo* na Ptujskem jezeru (SV Slovenija). Acrocephalus, 25(123), 201–205.

Denac, D. & J. Smole (2005): Črnoglavi galeb *Larus melanocephalus*. Acrocephalus, 26(127), 198.

Deutsch, A. & A. Buchheim (1999): Breeding attempt of a probable hybrid Mediterranean Gull × Black-headed Gull *Larus melanocephalus* × *Larus ridibundus* in Germany. In: Meininger, P. L., W. Hoogendorn, R. Flamant & P. Raevel (eds.): Proc. 1st International Mediterranean Gull Meeting, 4–7 September 1998, Le Portel, Pas-de-Calais, France. EcoNum, Bailleul, pp. 151–154.

Gergelj, J., A. Žuljević & O. Sekereš (2004): Dinamika brojnosti parova i migracija crnoglavog galeba *Larus melanocephalus* sa kolonije na Palićkom jezeru. Ciconia, 13, 122–127.

Geister, I. (1984): Črnoglavi galeb *Larus melanocephalus*. Acrocephalus, 5(21), 45–46.

Geister, I. (1995): Ornitološki atlas Slovenije. Državna založba Slovenije, Ljubljana, 287 str.

Glutz von Blotzheim, U. N. & K. M. Bauer (1999): Handbuch der Vögel Mitteleuropas. Band 8/1. Charadriiformes (3. Teil). AULA-Verlag, Wiesbaden.

Harrison, C. (1975): A field guide to the nests, eggs and nestlings of European birds with North Africa and the Middle East. Collins, London, 432 p.

Kerček, M. (2005): Ptice akumulacije Medvedce. Diplomsko delo. Pedagoška fakulteta, Univerza v Mariboru, Maribor, 99 str.

Kmecl, P. & K. Rižner (1993): Pregled vodnih ptic in ujed Cerkniškega jezera; spremljanje številčnosti s poudarkom na preletu in prezimovanju. Acrocephalus, 14(56–57), 4–31.

Kralj, J. (1997): Ornitofauna Hrvatske tijekom posljednjih dvjesto godina. Larus, 46, 1–112.

Laber, J. (2000): Die Brutbestandsentwicklung der Schwarzkopfmöwe (*Larus melanocephalus*) im Seewinkel. Egretta, 43(2), 112–118.

Meininger, P. L. & R. Flamant (1999): Breeding populations of Mediterranean Gull *Larus melanocephalus* in The Netherlands and Belgium. In: Meininger, P. L., W. Hoogendorn, R. Flamant & P. Raevel (eds.): Proc. 1st International Mediterranean Gull Meeting, 4–7 September 1998, Le Portel, Pas-de-Calais, France. EcoNum, Bailleul, pp. 47–54.

Mršić, N. (1997): Biotska raznovrstnost v Sloveniji. Ministrstvo za okolje in prostor, Uprava RS za varstvo narave, Ljubljana, 129 str.

Radović, D., J. Kralj, V. Tutiš, J. Radović & R. Topić (2005): Nacionalna ekološka mreža – važna područja za ptice u Hrvatskoj. DZZP, Zagreb, 84 str.

Rubinič, B. (1995): Črnoglavi galeb *Larus melanocephalus* in njegov status na slovenski obali. Annales, Ser. Hist. Nat., 5(1), 81–85.

Smole, J. (2001): Prvi teritorialni črnoglavi galeb *Larus melanocephalus* v Sloveniji. Acrocephalus, 22(109), 225–226.

Štumberger, B. (2000): Reka Drava. V: Polak, S. (ur.): Mednarodno pomembna območja za ptice v Sloveniji. DOPPS, Ljubljana, str. 149–159.

Šmon, M. (2000): Drava, vir električne energije. V: Macuh, P., M. Šmon, I. Verboten, M. Kanop & I. Žiberna (ur.): Drava nekoč in danes. Obzorja, Maribor, str. 370–425.

Tome, D., A. Sovinc & P. Trontelj (2005): Ptice Ljubljanskega barja. Monografija DOPPS št. 3, Ljubljana.

Uradni list RS (2004): Uredba o posebnih varstvenih območjih (območjih Natura 2000). UL RS 49/2004, Ljubljana, 30. 4. 2004.

Varga, L., R. Veprik, J. Gergely, A. Széll, L. Csihar & I. Staudinger (1996): A magyar szerecsensirály (*Larus melanocephalus*) gyúrúzési program elsó eredményei. Túzok, 1(3), 116–123.

Vogrin, M. (1990): Galebi na polju. Acrocephalus, 11(46), 103–104.

Wagener, M. (1998): Praktische Hinweise für brutbiologische Untersuchungen an der Flußseeschwalbe *Sterna hirundo*. Vogelwelt, 119, 279–286.

Zielińska, M., P. Zieliński, P. Kołodziejczyk, P. Szewczyk & J. Betleja (2007): Expansion of the Mediterranean Gull *Larus melanocephalus* in Poland. J. Ornithol., 148(4), 543–548.

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NEW RECORD OF THE HUMPBACK WHALE *(MEGAPTERA NOVAEANGLIAE)* IN THE ADRIATIC SEA

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ABSTRACT

A report is submitted herein on the occurrence of a humpback whale in Slovenian territorial waters (Gulf of Trieste, North Adriatic Sea) during February, March and April 2009. This is the first confirmed and documented record of this species for Slovenia and the Gulf of Trieste, the second for the Adriatic Sea and the 14th for the Mediterranean Sea. The whale was observed from the coast and from a small inflatable boat. Its dorsal fin, tail fluke and other body parts were photographed for the purposes of photo-identification and dive times were recorded. The animal was estimated to be a sub-adult or a young adult, about 10–12 m long, apparently in good body condition. It is possible that the whale had come into the area by following food sources.

Key words: humpback whale, *Megaptera novaeangliae*, Adriatic Sea, Gulf of Trieste, Slovenia

NUOVA SEGNALAZIONE DI MEGATTERA *(MEGAPTERA NOVAEANGLIAE)* IN MARE ADRIATICO

SINTESI

L'articolo tratta l'avvistamento di una megattera in acque territoriali slovene (Golfo di Trieste, Adriatico settentrionale) nei mesi di febbraio, marzo ed aprile del 2009. Si tratta della prima segnalazione confermata e documentata della specie per la Slovenia e per il Golfo di Trieste, la seconda per l'Adriatico e la quattordicesima per il Mediterraneo. La megattera è stata avvistata sia dalla costa che con l'ausilio di una piccola imbarcazione gonfiabile. La pinna dorsale, la coda e le altre parti del corpo sono state fotografate per la foto-identificazione dell'animale. È stata inoltre registrata la durata delle immersioni della megattera. È stato valutato che si tratti di un esemplare quasi adulto, della lunghezza di 10–12 m, apperantemente in buone condizioni. Gli autori suppongono che la megattera sia arrivata nel Golfo di Trieste seguendo risorse alimentari.

Parole chiave: megattera, *Megaptera novaeangliae*, mare Adriatico, Golfo di Trieste, Slovenia

INTRODUCTION

The humpback whale (*Megaptera novaeangliae*) is a cosmopolitan species, found in all oceans of the world (Clapham, 1996; Clapham & Mead, 1999). The life cycle of the species consists of two main parts: during spring, summer and autumn, the whales are found in high-latitude areas, where most of the feeding takes place; in winter, whales spend time in the tropics and subtropics, where mating and calving takes place (Clapham, 1996). However, not all whales undertake the seasonal migration to the breeding areas (Brown *et al.*, 1995).

In the North Atlantic, humpback whales can be found from tropical waters to the arctic pack ice (Smith *et al.*, 1999). Whales from virtually all areas of the North Atlantic breed in the West Indies in winter and probably belong to one panmictic population (Katona & Beard, 1990; Clapham *et al.*, 1993; Mattila *et al.*, 1994; Larsen *et al.*, 1996; Clapham & Mead, 1999), although some data suggest that an eastern tropical North Atlantic breeding ground, possibly in the historic mating and calving ground off Cape Verde Islands, might also exist (Larsen *et al.* 1996; Jann *et al.*, 2003; Smith & Reeves, 2003).

The humpback whale is not regularly present in the Mediterranean Sea, where it is considered an occasional or visitor species (Frantzis *et al.*, 2004; Reeves & Notarbartolo di Sciara, 2006). The known occurrences of the humpback whale in the Mediterranean Sea are presented in Table 1. In 2002, a single (and very emaciated) humpback whale was observed off Senigallia, Italy, which is the only record of this species in the Adriatic to date (Affronte *et al.*, 2003).

The only species of large whales recorded in the Gulf of Trieste (North Adriatic Sea) to date are the fin whale *(Balaenoptera physalus)* and the sperm whale *(Physeter macrocephalus),* the former being occasional in the area and the latter being very rare (Kryštufek & Lipej, 1993; Lipej *et al.*, 2004).

Herein, we report on the occurrence of a single humpback whale in Slovenian territorial waters (Gulf of Trieste, North Adriatic Sea) during February, March and April 2009. This is the first confirmed and documented record of this species for Slovenia and the Gulf of Trieste, the second for the Adriatic Sea, and the 14th for the Mediterranean Sea.

Tab. 1: Known records of the humpback whale *(Megaptera novaeangliae)* ***occurrence in the Mediterranean Sea (adapted from Reeves & Notarbartolo di Sciara (2006).***
Tab. 1: Doslej znana pojavljanja kita grbavca *(Megaptera novaeangliae)* ***v Sredozemlju; prirejeno po Reeves & Notarbartolo di Sciara (2006).***

Date	Location	Sex	Size	Notes	Reference
Nov 1885	Toulon, France		6.8 m	by-caught	Aguilar, 1989
14 Mar 1986	Majorca, Baleares, Spain			sighting of two individuals, possibly a female with calf	Aguilar, 1989
Mar 1990	Bay of Aiguablava, Catalonia, Spain			sighting of one possible adult	personal comm. from A. Aguilar to Frantzis *et al.*, 2004
2 Oct 1992	Gulf of Gabés, Tunisia		8 m	by-caught	Chakroun, 1994
21 May 1993	Cavalaire, France	F	7 m	by-caught	Bompar, 2000
Aug 1993	Toulon, France			sighting of two individuals	personal comm. from R. Sears to Frantzis *et al.*, 2004
24 Jan 1998	Gulf of Oristano, W. Sardinia, Italy		7–8 m	sighting	Frantzis *et al.*, 2004
17 Apr 2001	Bay of Tolo, Myrtoon Sea, Greece		8–11 m	sighting	Frantzis *et al.*, 2004
19 Jul 2002	Lefkada Island, Greece			sighting	Frantzis *et al.*, 2004
4 Aug 2002	Senigallia, Italy			sighting	Affronte *et al.*, 2003
5 Apr 2003	Tartous, Syria	M	785 cm	stranded dead	Saad, 2004
17 Feb 2004	Corfu Island, Greece	F	7.2 m	by-caught	Frantzis *et al.*, 2004
2 Apr 2004	Siracusa, Sicily, Italy		about 10 m	by-caught alive and released	Centro Studi Cetacei, 2006
Feb-Apr 2009	Slovenian waters, Gulf of Trieste		10–12 m	repeated sightings	this paper

MATERIAL AND METHODS

We received initial reports on whale sightings from Slovenian harbour masters and local fishermen. We were able to respond to one of these reports (made by a phone call), located the animal and identified the species. The whale was observed from the coast (from high vantage points) and from a small inflatable boat. Photographs of right and left sides of the dorsal fin and the ventral side of the tail fluke were taken for the purpose of photo-identification. Additionally, photos and video footage of the rostrum, blowhole, pectoral fins, thorax, tail stock and dorsal side of the tail fluke were taken, in order to assess the animal's condition. When the whale was observed from a boat, time and GPS position were recorded throughout each sighting, and the whale's dives were timed with a stopwatch and recorded onto the data sheets (except during the first sighting, in which photo-identification and assessment of the animal's condition was the primary objective). A biopsy was performed with a crossbow and a biopsy dart, and a sample taken for genetic, toxicological and other analyses, as well as sex determination.

RESULTS

The initial report of a whale was received on 10 February 2009. At the time, the species was unknown. The whale was spotted by fishermen and local people several times in the next few days, but the species was not identified, although some descriptions *(i.e.*, very long pectoral fins) indicated that it might be a humpback whale. On February 16th, the authors responded to a phone call about a whale sighting, managed to locate the whale and to identify the species as the humpback whale. The animal was estimated to be about 10–12 m long, compared to the research vessel (5.7 m). It appeared to be in good body condition (Fig. 1). The animal was poorly to moderately scarred.

The whale was mostly observed performing regular surfacings, with occasional fluke-ups. It would often change direction while swimming, but sometimes followed the same course for periods of up to one hour. Breaching, where the whole body except the tail fluke left the water, was also observed. On several occasions, the animal was seen swimming on the side, with one lobe of the tail fluke out of the water, or slowly spinning around the body axis, just below the water surface. Direct feeding, production of bubbles or open mouth was not observed.

Large numbers of gilt sardines *(Sardinella aurita)* were reported in the area in that period and numerous specimens were seen lying motionless on the water surface or swimming feebly belly up in the vicinity of the whale. Moreover, large aggregations of seagulls were seen feeding in the same area.

The durations of a total of 845 dives were recorded. Dive time duration ranged between 3 seconds and 5 minutes 28 seconds, although on the first day of observation (when dive times were not systematically re-

Fig. 1: Humpback whale *(Megaptera novaeangliae)* ***in Slovenian waters, apparently in good condition. (Photo: T. Genov)***
Sl. 1: Očitno zdrav kit grbavec *(Megaptera novaeangliae)* ***v slovenskih vodah. (Foto: T. Genov)***

corded), the whale also performed dives lasting up to 10 minutes. For most of the time, the whale performed a series of 2-3 short dives, usually lasting between 3-30 seconds, followed by a single long dive, usually lasting between 1 and 4 minutes. The mean duration of the dives was 49 seconds. Among all dives recorded, 13% (n = 108) of all dives lasted <15 seconds, 59% (n = 502) between 15 and 60 seconds, and 28% (n = 235) >60 seconds. The mean duration of dives lasting more than 1 minute was 2 minutes 4 seconds.

The whale was observed mostly in waters off the town of Piran, in an area covering approximately 27 km^2. It remained relatively close to the coast, with the shortest distance of 200 m and the longest of 2.8 km from shore. Depths in the area where the whale was observed ranged between 12 and 38 m. The animal remained in the area until the middle of March, when it moved to the Italian side of the Gulf of Trieste, to the shallow waters (roughly between 4 and 10 meters of depth) off the town of Grado. It then returned to Slovenian waters within a few days. Soon after, the whale apparently disappeared in the second half of March, but then briefly re-appeared in the second half of April.

DISCUSSION

The mean length of physically mature male and female humpback whales is 13.0 m and 13.9 m, respectively (data from Chittleborough, 1965, in Clapham & Mead, 1999). From the same data, mean lengths at independence (one year of age) were 9.9 m for males and 9.7 for females. Mean lengths at the average age at attaining sexual maturity (five years) were 11.8 m for males and 11.9 m for females. Based on the estimated size of the whale and the data above, and on the amount of scarring on the body (Chu & Nieukirk, 1988), we assume the animal to be a sub-adult or a young adult. It is likely that the animal is on the brink of attaining sexual maturity, but has not yet attained physical maturity or maximum size. The whale appeared to be in good body condition. The physical appearance of the whale did not differ from typical humpback whales (believed to be in good health) in the Atlantic (R. Seton, *pers. comm.*; T. Genov, *pers. observ.)*. The animal showed no abnormal behaviour or any signs of illness or distress.

Humpback whale groups are small and unstable in majority of cases, with individuals frequently changing associates, although some long-term associations have been recorded (Clapham, 1993). Single animals are commonly observed (Clapham, 1993). Therefore, a single humpback whale is no exceptional event. However, data from the North Atlantic feeding ground (Clapham, 1993) suggest that most single animals are juveniles of either sex. This would support the possibility of the animal reported here being a sub-adult.

Dive times were similar to those reported for feeding humpback whales in Alaska (Dolphin, 1987). In that study, the majority of dives were shorter than 2.8 min, which was the overall average for all dives (including those over depths of up to 120 m). The average value of dives for whales feeding over depths of up to 20 m (similar to depths in the present paper) was 1.21 min (Dolphin, 1987), but singing humpback whales can also dive for more than 10 minutes (Chu, 1988).

It is impossible to determine whether the whale was feeding in the area or not. However, the lateral swimming by the animal, the presence of gilt sardines and seagulls feeding on the water surface in the vicinity of the whale suggest feeding activity. Humpback whales are known to feed, among other prey species, on *Sardina* sp. and *Sardinella* sp. (Clapham & Mead, 1999). Furthermore, the dive pattern, mostly characterised by a few short dives, followed by a long one, is consistent with possible feeding.

Photo-ID comparison with the North Atlantic Humpback Whale Catalogue (NAHWC), which currently contains over 6,000 individual humpback whales and is curated at the College of Atlantic (Seton *et al.*, 2002), did not produce any matches (R. Seton, *pers. comm.)*. The whale will be given a new HWC# code and added to the NAHWC catalogue. Analyses of skin samples are pending.

The humpback whale used to be considered rare in the Mediterranean (Aguilar, 1989), but the number of records in the last 20 years has increased (Frantzis *et al.*, 2004). This increase in humpback whale sightings could be the result of previous sightings going unreported or of an actual increase in the occurrence of the species in the region (Frantzis *et al.*, 2004). The reason why this animal was found in the North Adriatic, one of the narrowest and remotest parts of the Mediterranean, remains unknown. The apparently good health status of the whale and the presence of large numbers of gilt sardines (which are not very common in the area), suggest that the whale followed food sources rather than becoming disorientated or lost.

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NOVO OPAŽANJE KITA GRBAVCA (*MEGAPTERA NOVAEANGLIAE*) V JADRANSKEM MORJU

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Ključne besede: kit grbavec, *Megaptera novaeangliae*, Jadransko morje, Tržaški zaliv, Slovenija

REFERENCES

Affronte, M., L. A. Stanzani & G. Stanzani (2003): First record of a humpback whale, *Megaptera novaeangliae* (Borowski, 1781) in the Adriatic Sea. Annales, Ser. Hist. Nat., 13(1), 51–54.

Aguilar, A. (1989): A record of two humpback whales, *Megaptera novaeangliae*, in the western Mediterranean Sea. Mar. Mamm. Sci., 5(3), 306–309.

Bompar, J.-M. (2000): Les cétacés de Méditerranée. Edisud, La Calade, Aix-en-Provence, 188 p.

Brown, M. R., P. J. Corkeron, P. T. Hale, K. W. Schultz & M. M. Bryden (1995). Evidence for a sex-segregated migration in the humpback whale (*Megaptera novaeangliae*). Proc. R. Soc. Lond. B, 259, 229–234.

Centro Studi Cetacei (2006): Cetacei spiaggiati lungo le coste italiane. XIX. Rendiconto 2004. Atti Soc. Ital. Sci. Nat., Atti Mus. Civ. Stor. Nat. Milano, 147(1), 145–157.

Chakroun, F. (1994): Status of cetaceans in Tunisian marine waters. Eur. Res. Cetaceans, 8, pp. 107.

Chittleborough, R. G. (1965): Dynamics of two populations of the humpback whale, *Megaptera novaeangliae* (Borowski). Aust. J. Mar. Freshw. Res., 16, 33–128.

Chu, K. (1988): Dive times and ventilation patterns of singing humpback whales *(Megaptera novaeangliae).* Can. J. Zoo., 66, 1322–1327.

Chu, K. & S. Nieukirk (1988): Dorsal fin scars as indicators of sex, age and social status in humpback whales *(Megaptera novaeangliae).* Can. J. Zoo., 66, 416–420.

Clapham, P. J. (1996): The social and reproductive biology of humpback whales: an ecological perspective. Mamm. Rev., 26, 27–49.

Clapham, P. J. & J. G. Mead (1999): *Megaptera novaeangliae*. Mamm. Species, 604, 1–9.

Clapham, P. J., D. K. Mattila & P. J. Palsb ll (1993): High-latitude-area composition of humpback whale groups in Samana Bay: further evidence for panmixis in the North Atlantic population. Can. J. Zool., 71, 1065–1066.

Dolphin, W. F. (1987): Dive behavior and estimated energetic expenditure of foraging humpback whales in southeast Alaska. Can. J. Zoo., 65, 354–362.

Frantzis, A., O. Nikolaou, J.-M. Bompar & A. Cammedda (2004): Humpback whale *(Megaptera novaeangliae)* occurrence in the Mediterranean Sea. J. Cetacean Res. Manage., 6(1), 25–28.

Jann, B., J. Allen, M. Carrillo, S. Hanquet, S. K. Katona, A. R. Martin, R. R. Reeves, R. Seton, P. T. Stevick & F. W. Wenzel (2003): Migration of a humpback whale *(Megaptera novaeangliae)* between the Cape Verde Islands and Iceland. J. Cetacean Res. Manage., 5(2), 125–29.

Katona, S. K. & J. C. Beard (1990): Population size, migrations and feeding aggregations of the humpback whale *(Megaptera novaeangliae)* in the western North Atlantic Ocean. Reports of the International Whaling Commission, Spec. Issue 12, 195–305.

Kryštufek, B. & L. Lipej (1993): Whales (Cetacea) in the northern Adriatic. Annals for Istrian and Mediterranean Studies, 3, 9–20. *(In Slovene)*

Larsen, A. H., J. Sigurjónsson, N. ien, G. Vikingsson, & P. J. Palsb ll (1996): Population genetic analysis of nuclear and mitochondrial loci in skin biopsies collected from Central and northeastern North Atlantic humpback whales *(Megaptera novaeangliae):* population identity and migratory destinations. Proc. R. Soc. Lond. B, 263, 1611–1618.

Lipej, L., J. Dulčić & B. Kryštufek (2004): On the occurrence of the fin whale *(Balaenoptera physalus)* in the northern Adriatic. J. Mar. Biol. Ass. U.K., 84, 861–862.

Mattila, D. K., P. J. Clapham, O. Vasquez & R. Bowman (1994): Occurrence, population composition and habitat use of humpback whales in Samana Bay, Dominican Republic. Can. J. Zoo., 71, 1898–1907.

Reeves, R. R. & G. Notarbartolo di Sciara (2006): The status and distribution of cetaceans in the Black Sea and Mediterranean Sea. IUCN Centre for Mediterranean Cooperation, Malaga, Spain. 137 p.

Saad, A. (2004): First record of a humpback whale stranding on the coast of Syria (Eastern Mediterranean). FINS, 1(1), pp. 10.

Seton, R. E., J. M. Allen & S. K. Todd (2002): Curation of the North Atlantic Humpback Whale Catalogue and Associated Databases. Progress Report to Northeast Fisheries Science Center (NEFSC), National Marine Fisheries Service. College of the Atlantic, Bar Barbor, Maine, 10 p.

Smith, T. D. & R. R. Reeves (2003): Estimating American 19th Century Catches of Humpback Whales in the West Indies and Cape Verde Islands. Caribb. J. Sci., 39(3), 286–297.

Smith, T. D., J. Allen, P. J. Clapham, P. J. Hammond, S. Katona, F. Larsen, J. Lien, D. Mattila, P. J. Palsb ll, J. Sigurjónsson, P. T. Stevick & N. Øien (1999): An ocean-basin-wide mark-recapture study of the North Atlantic humpback whale *(Megaptera novaeangliae).* Mar. Mamm. Sci., 15(1), 1–32.

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ANALISI DI DATI BIOACUSTICI OTTENUTI MEDIANTE ECHOSOUNDER PER LA VALUTAZIONE DELLA COMPONENTE ITTICA DELL' AREA MARINA PROTETTA DI MIRAMARE

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SINTESI

Le tecniche acustiche attive, essendo metodi non invasivi, rappresentano un valido strumento, complementare ai censimenti visivi ("visual census"), per lo studio e il monitoraggio della componente ittica all'interno di un'area marina protetta. Nel periodo compreso tra Aprile e Novembre 2006, l'utilizzo di un echosounder scientifico split-beam ha permesso di ottenere stime quantitative della distribuzione spaziale dei popolamenti ittici dell'AMP di Miramare (Golfo di Trieste, Alto Adriatico) e di individuare potenziali aree di aggregazione ittica. La zona della barriera, la zona del FAD (fish aggregating device) e la zona al limite settentrionale dell'AMP si caratterizzano per la frequenza con cui si sono rilevati elevati valori di densità ittica nel corso del periodo di campionamento. I risultati ottenuti dal presente studio costituiscono utili informazioni per la gestione e la valutazione dell'efficacia di gestione della AMP.

Parole chiave: Area Marina Protetta di Miramare, densità ittica, echosounder

ANALYSIS OF BIOACOUSTICAL DATA FROM ECHOSOUNDER SURVEYS FOR THE ASSESSMENT OF THE FISH POPULATIONS IN THE MARINE PROTECTED AREA OF MIRAMARE

ABSTRACT

Active hydroacoustic techniques are non-invasive methods for the study and monitoring of fish populations. These techniques are well-applied in marine protected areas and can be used as a complementary technique to a visual census. A split-beam echosounder was employed during the period from April to November 2006, to obtain a quantitative assessment of the spatial distribution of the fish populations in the MPA of Miramare (Gulf of Trieste, northern Adriatic Sea) and to identify potential fish-aggregating areas. High values of fish density were recorded with higher frequency in the reef zone, in the FAD zone and in the north limit core zone throughout the survey period. The results obtained from the current study provide useful information for the management and evaluation of the management effectiveness of the MPA.

Key words: Marine Protected Area of Miramare, fish density, echosounder

INTRODUZIONE

La quantificazione della componente ittica e della sua distribuzione nello spazio e nel tempo è essenziale per valutare l'efficacia dell'azione di protezione di un'area marina protetta (Pomeroy *et al.*, 2004). Ciò permette inoltre all'ente gestore di pianificare azioni e strategie gestionali delle risorse ittiche entro e fuori i confini della zona sotto tutela. L' Area Marina Protetta (AMP) di Miramare (Golfo di Trieste, Alto Adriatico) racchiude un ambiente unico per la struttura geomorfologica e la posizione geografica e rappresenta un sito fondamentale per l'elevata densità e biodiversità di specie ittiche (Costantini *et al.*, 2004). Da diversi anni la comunità ittica della AMP di Miramare viene monitorata tramite censimenti visuali ("visual census"), tecnica non invasiva di monitoraggio (AA.VV., 1999) che viene applicata in tutte le aree marine protette italiane (Vacchi & La Mesa, 1999). Fattori ambientali (scarsa visibilità, bassa temperatura, cattive condizioni meteorologiche) e fattori legati alla soggettività delle osservazioni costituiscono, però, importanti limiti a tale metodologia. L'utilizzo di tecniche acustiche attive non solo permette di operare anche quando le condizioni meteo-marine non sono ottimali per svolgere il "visual census", ma consente anche di aumentare l'estensione della zona monitorata.

La misura dell'abbondanza dei popolamenti ittici è probabilmente la più importante applicazione delle tecniche acustiche nella ricerca scientifica nel settore ittico (MacLennan, 1990). Stime quantitative possono essere ricavate mediante "echo integration", tecnica che si basa sulla stima dell'energia riflessa da un determinato volume d'acqua e che viene comunemente utilizzata per la valutazione di stock ittici d'importanza commerciale (Misund, 1997). Le metodologie acustiche forniscono stime di abbondanza indipendenti dalle attività di pesca e pertanto possono essere applicate in aree marine protette in sostituzione dei comuni metodi di campionamento che necessitano di catturare una parte o l'intero campione studiato. Sia echosounder operanti da barca che trasduttori stazionari si sono rivelati utili strumenti per la quantificazione e la valutazione della distribuzione spaziale e del comportamento dei popolamenti ittici in strutture artificiali quali piattaforme petrolifere (Stanley & Wilson, 1998; Stanley & Wilson, 2000; Soldal *et al.*, 2002) o barriere (Thorne *et al.*, 1989; Fabi & Sala, 2002; Sala *et al.*, 2007).

Lo scopo del presente studio è stato quello di valutare la distribuzione spaziale della componente ittica dell'Area Marina in diversi periodi dell'anno mediante tecniche acustiche attive non stazionarie, al fine di ottenere informazioni utili alla pianificazione di azioni e strategie di gestione delle risorse ittiche da parte dell'ente gestore. L'obiettivo principale è stato quello di mettere in evidenza potenziali aree di elevata aggregazione ittica, che potranno essere tutelate in modo particolare.

MATERIALI E METODI

Area di studio

L'Area Marina Protetta di Miramare (Golfo di Trieste, Alto Adriatico) è situata a 8 km di distanza dalla città di Trieste, in direzione Nord Ovest ed è gestita dal W.W.F. – Italia a partire dal 1986, anno di fondazione. Essa comprende un tratto di costa di circa 1500 m e si estende al largo per circa 600 m, coprendo una superficie totale di 120 ettari di mare. L'area marina protetta è suddivisa in due zone: la zona a protezione integrale (core), che copre 30 ettari e ha una massima profondità di 18 m, e la zona a protezione parziale (buffer), che invece copre i restanti 90 ettari e ha una massima profondità di circa 21 m. Nella zona a protezione integrale vige una stretta regolamentazione che vieta il prelievo di organismi viventi e di formazioni rocciose e sabbiose, impedisce la navigazione e non consente alcuna attività che possa essere contraria alle finalità di tutela e conservazione dell'area. Sono possibili solo attività di ricerca scientifica e monitoraggio, oltre ad alcune attività di fruizione regolamentate dall'Ente Gestore. Nella zona a protezione parziale, istituita nel 1995 con ordinanza della Capitaneria di Porto di Trieste, sono vietati l'ancoraggio e la pesca sotto qualsiasi forma, con l'esclusione di quella sportiva esercitata da terra. La posizione geografica e la struttura geomorfologica che quest'area presenta ne fanno un ambiente unico e rappresentativo del Golfo di Trieste. La varietà dei substrati (rocciosi, sabbiosi e pelitici) (Tempesta *et al.*, 1996), le escursioni di marea e le variazioni termoaline annue, in gran parte causate dalla bora e dalle piene dei fiumi Isonzo e Timavo, influenzano le comunità di organismi presenti nella AMP.

All'interno della zona a protezione integrale è situata una barriera artificiale la cui posa in opera risale al 1978. Su un fondale fangoso di 16–17 m, a circa 150 m dallo spigolo del castello di Miramare, è stato posizionato un tumulo di grossi tubi di cemento del vecchio acquedotto di Trieste, del diametro di 1,5 m, disposti in modo irregolare. La barriera ha lunghezza 30 m, larghezza 6 m e altezza 3 metri nel punto più alto. La sua struttura disordinata ha permesso di creare diverse situazioni favorevoli all'attecchimento di specie sessili, nonché di fungere da riparo per banchi di diverse specie ittiche (Odorico & Ciriaco, 2004). Sempre all'interno della zona a protezione integrale, a una distanza di circa 70 m dalla costa e profondità 10 m, si trova un FAD (Fish Aggregating Device). Tale struttura, messa in posa nel 1996, è una Struttura Artificiale Leggera (SAL) con funzione aggregante, costituita da tubi corrugati di polietilene disposti in modo tale da formare una sfera di 4 m di diametro, caratterizzata da un asse centrale e 8 meridiani. Attualmente, a distanza di anni dalla posa in opera, il SAL si trova posato al fondo, essendo collassato a causa del peso delle incrostazioni (Odorico, 1997).

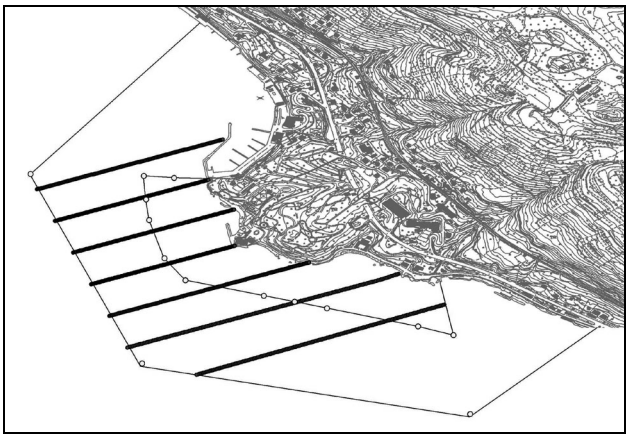

Fig. 1: Area Marina Protetta di Miramare e disegno sperimentale di campionamento.
Sl. 1: Območje Naravnega morskega rezervata Miramare in načrt vzorčenja.

Campionamenti acustici

I campionamenti acustici sono stati eseguiti mediante un echosounder Biosonics DT-X 5000 Transducer 200 kHz Split-beam. La raccolta delle coordinate geografiche da associarsi ai dati bioacustici è avvenuta grazie a un GPS Trimble TDC1. I dati acustici sono stati raccolti lungo 7 transetti paralleli equispaziati (Fig. 1), ciascuno dei quali è stato diviso in unità elementari di campionamento (EDSU – elementary distance sampling unit) di lunghezza pari a circa 10 m. Un'unità elementare di campionamento è la lunghezza della rotta entro cui le misure acustiche sono mediate per dare un unico valore che si considera rappresentativo della densità ittica al centro della EDSU (MacLennan & Simmonds, 1992). I dati acustici sono stati raccolti con cadenza circa mensile in un periodo compreso tra Aprile e Novembre 2006 e precisamente nei giorni 21.4., 18.5., 31.7., 7.8., 28.8., 1.9., 28.9., 26.10. e 9.11., per un totale di 9 uscite per ogni transetto acustico. I campionamenti sono stati effettuati in un intervallo compreso fra le 9.00 am e le 12.00 am. La raccolta dei dati acustici è stata effettuata mediante l'utilizzo del software di acquisizione Biosonics Visual Acquisition 4.02. I parametri utilizzati durante i campionamenti sono stati: "pulse width" (durata dell'impulso): 0,2 ms; frequenza di emissione: 208 kHz; "pulse per second" (numero di impulsi emessi al secondo): 4 pps; "data threshold" (valore soglia): -90 dB. Tutti i segnali al di sopra di questa soglia ricevuti dal trasduttore sono stati registrati. La velocità di crociera durante i campionamenti è stata di 2–3 nodi. Durante i campionamenti acustici una bassa velocità di crociera è importante per minimizzare possibili errori sistematici nelle stime quantitative che possono derivare dalla presenza di bolle d'aria negli strati d'acqua superficiali e dal movimento del trasduttore.

Analisi dei dati

Per l'analisi dei dati è stato utilizzato il software di analisi Biosonics Visual Analyzer versione 4.02. L'elaborazione dei dati acustici è stata divisa in diverse fasi: (1) la visualizzazione dei dati acustici e operazioni preliminari all'analisi; (2) l' analisi della "target strength"; (3) il calcolo della sezione trasversale acustica media; (4) l'echo integration e il calcolo delle densità ittiche.

In una prima fase, i dati acustici sono stati rappresentati in ecogrammi dopo aver inserito come input nel programma di analisi il coefficiente di calibrazione, ricavato secondo i metodi descritti dai protocolli della ditta costruttrice (AA.VV., 2004), un valore soglia pari a -65 dB, e i valori di temperatura e salinità della colonna d'acqua rilevati prima di ogni campionamento grazie alla sonda multiparametrica Idronaut mod. 316. I valori acquisiti dalla sonda ogni 0,1 m di profondità a partire da 0,25 m al di sotto della superficie sono stati mediati per l'intera colonna d'acqua. Sono stati esclusi dall'analisi lo strato della colonna d'acqua subito al di sopra del fondale, zona in cui lo strumento acustico non riesce a discriminare gli oggetti sonificati (MacLennan & Simmonds, 1992), e lo strato d'acqua superficiale, caratterizzato dalla presenza di bolle d'aria causate dal movimento dell'imbarcazione e da fattori meteo-marini. L'ampiezza di tali strati è stata rispettivamente di 40cm e 200 cm.

Per poter convertire l'energia acustica riflessa in densità (numero di pesci per m^2 o m^3) è necessario stimare la sezione trasversale acustica (σ) delle specie oggetto di studio. La sezione trasversale acustica e la target strength (TS) sono vie alternative per descrivere la capacità di un bersaglio di riflettere l'energia acustica ma σ è una misura lineare espressa in m^2, mentre TS è una misura logaritmica espressa in dB (MacLennan & Simmonds, 1992). Nel presente studio i valori di TS sono stati ricavati mediante misure *in situ*, data l'impossibilità di effettuare delle pescate e mancando studi pregressi sulle proprietà di riflessione acustica delle specie ittiche della AMP di Miramare. Per l'analisi della TS sono state utilizzate tutte le registrazioni effettuate nel corso dei campionamenti. Ogni registrazione è stata analizzata con appositi algoritmi del software di analisi alla ricerca di target singoli ("single target analysis"), cioè dei pesci sufficientemente lontani uno dall'altro, così da essere risolvibili acusticamente.

A questo punto, in base a tutti i valori di TS ottenuti dalla "single target analysis", si è calcolato un valore medio della sezione trasversale acustica. Per ottenere delle stime confrontabili nel tempo e nello spazio, si è utilizzato lo stesso valore di σ per convertire l'energia acustica ottenuta con il processo di echo integration. Per

ogni target singolo il valore in dB di target strength è stato convertito in m^2 secondo la formula:

$$\sigma_{bs} = 10^{TS/10}$$

Quindi, calcolando la media aritmetica dei nuovi valori, si è ottenuta una sezione trasversale acustica media pari a: $4{,}5262\times10^{-6}$ m^2. Tale valore è stato inserito nel software di analisi per convertire i valori di energia ottenuti mediante il processo di echo integration in densità ittiche. La tecnica dell'echo integration permette di calcolare l'energia proveniente da un determinato volume d'acqua. Il trasduttore converte le onde acustiche ricevute in energia elettrica. Il voltaggio generato è trasformato dalla forma analogica a quella digitale: ogni impulso emesso ("ping") risulta quindi descritto da una serie discreta di valori, chiamati "samples". Nell'echo integration ogni sample superiore ad una determinata soglia viene elevato al quadrato e sommato ai precedenti. La somma dei quadrati dei samples viene quindi divisa per il numero totale dei samples misurati e moltiplicata per parametri ambientali e di calibrazione per dare la "volume backscattering strength" (S_v), che è una misura dell'energia media riflessa dal volume d'acqua considerato. Gli algoritmi usati dal Visual Analyzer nell'echo integration calcolano S_v in termini di dB come:

$$S_v = 10 \log [\rho_c \cdot (\sum P / \sum \text{samples})$$

dove *P* sono i valori di intensità dei samples, corretti secondo la funzione 20 log R TVG ed elevati al quadrato, e ρ_c è la "system scaling constant", una costante che dipende da fattori ambientali e di calibrazione (AA.VV., 2004). Nell'analisi degli ecogrammi del presente studio, il software è stato impostato in modo tale da avere un valore di S_v per ogni unità elementare: l'energia acustica, cioè, è stata mediata su distanze pari alla lunghezza della EDSU (circa 10 m) per dare un valore unico. Mediante specifici algoritmi del software di analisi, i valori in dB di volume backscattering strength sono stati convertiti in densità di pesci per m^2 (FPUA – fish per unit area) utilizzando il valore di sezione trasversale acustica media precedentemente stimata pari a $4{,}5262\times10^{-6}$ m^2. E' importante notare che questo valore è una media calcolata su pesci di specie diverse e dimensioni diverse e per tale ragione le stime di densità devono essere considerate come indici relativi e non come misure assolute.

I dati di ogni campionamento sono stati riassunti in tabelle contenenti per ogni unità elementare (EDSU) le informazioni di latitudine e longitudine del punto iniziale e densità ittica per m^2 (FPUA). I valori di statistica descrittiva relativi a ciascun periodo di campionamento (Tab. 1) sono stati calcolati considerando le densità ittiche rilevate in tutte le EDSU di ogni transetto. La presunta non normalità della distribuzione dei dati che si può dedurre dalla statistica descrittiva è stata comunque testata con il test di Shapiro-Wilk, indicato per serie univariate di valori con $3 \leq N \leq 5000$ (Hammer *et al.*, 2008), il cui risultato ha consentito di respingere l'ipotesi nulla della distribuzione normale univariata. E' stato quindi usato il test di Kruskal-Wallis per capire se ci fossero significative differenze tra le 9 serie di dati corrispondenti ai campionamenti. Avendo a che fare con un numero molto elevato di dati relativi a diversi periodi si è deciso di procedere utilizzando tecniche di analisi statistica multivariata per poter rappresentare la struttura dei dati in uno spazio a dimensioni ridotte. La tecnica di ordinamento usata è stata l'analisi delle componenti principali (PCA). La matrice analizzata tramite PCA è formata da 435 righe che rappresentano le unità elementari (gli oggetti) e da 9 colonne che rappresentano i periodi di campionamento (le variabili), per un totale di quasi 4000 dati. L'elaborazione statistica dei dati è stata effettuata mediante il pacchetto di elaborazione statistica PAST (PAlaeontological STatistics) vers.1.78 (Hammer *et al.*, 2001).

Tab. 1: Valori di statistica descrittiva relativi alla FPUA (fish per unit area) rilevata in ogni campionamento.
Tab. 1: Opisna statistika vrednosti FPUA (fish per unit area = število rib na območno enoto), ugotovljenih v posameznih vzorčevalnih obdobjih.

	FPUA_AP	FPUA_MA	FPUA_LU	FPUA_AG07	FPUA_AG28	FPUA_SE01	FPUA_SE28	FPUA_OT	FPUA_NO
min	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1q	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
mediana	0,11	0,00	0,01	0,00	0,00	0,00	0,00	0,01	0,01
3q	0,24	0,03	0,07	0,00	0,00	0,00	0,05	0,03	0,06
max	3,72	62,70	38,28	19,17	19,32	337,62	454,55	87,82	302,63
N	435	435	435	435	435	435	435	435	435
media	0,224	0,397	0,554	0,214	0,230	1,403	2,647	0,746	2,682
devst	0,3464	3,6497	2,6684	1,6007	1,6245	17,0919	27,5807	5,8090	17,5184

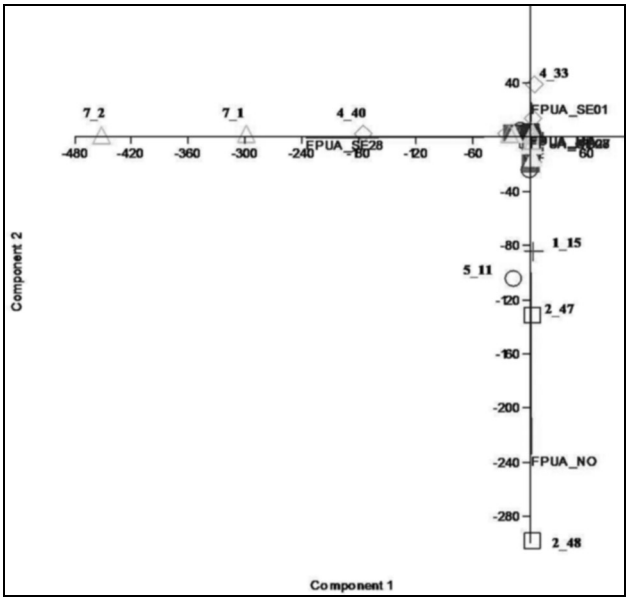

Fig. 2: Distribuzione dei valori di FPUA ottenuti dai campionamenti di Novembre 2006. Le unità elementari che si separano dalle altre nel profilo della PCA sono evidenziate con un quadrato.
Sl. 2: Razporeditev vrednosti FPUA (fish per unit area = število rib na območno enoto) novembra 2006. Osnovne enote, ločene od drugih na grafu PCA, so označene s kvadrati.

Note le coordinate geografiche associate a ciascuna unità elementare, si è deciso di rappresentare tramite il software ArcGIS 9, ArcMap vers. 9.2 i valori di densità ittica stimati in ogni mese in una mappa della AMP di Miramare, così da visualizzare e confrontare la distribuzione dei valori di FPUA lungo i transetti e facilitare l'identificazione delle unità elementari che nel diagramma della PCA si differenziano dalle altre nel contesto geografico dell'area di studio. Si è scelto di non rappresentare i valori di FPUA inferiori a 0,1 mentre i rimanenti valori sono stati discretizzati in 6 classi a ciascuna delle quali è stata associata una differente simbologia. Sono qui riportate le mappe contenenti le unità elementari poste in evidenza dalla PCA (Figg. 3, 4, 5).

RISULTATI

Dai valori di statistica descrittiva calcolati per ogni mese e riportati in tab.1 si deduce che la distribuzione dei dati è estremamente dispersa e asimmetrica. Il campo di variazione della FPUA è molto grande, ma la maggior parte dei valori si concentra vicino allo zero. Dal confronto tra le medie e le rispettive deviazioni standard si deduce quanto le densità ittiche stimate siano variabili all'interno di ogni mese. Le serie di dati del primo Settembre, del 28 Settembre e di Novembre si differenziano rispetto alle altre per la media aritmetica maggiore di 1 e i valori massimi dell'ordine delle centinaia. Anche la deviazione standard è molto alta, nell'ordine delle decine, rispetto agli altri campionamenti in cui si attesta intorno alle unità.

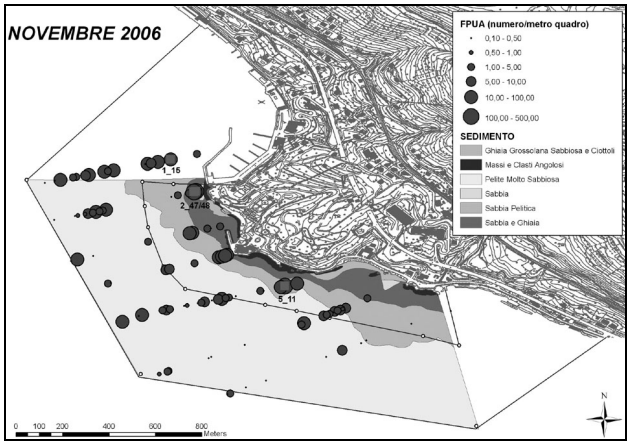

Fig. 3: Distribuzione dei valori di FPUA ottenuti dai campionamenti del primo Settembre 2006. Le unità elementari che si separano dalle altre nel profilo della PCA sono evidenziate con un quadrato.
Sl. 3: Razporeditev vrednosti FPUA 1. septembra 2006. Osnovne enote, ločene od drugih na grafu PCA, so označene s kvadrati.

La Tabella 2 riporta i valori di probabilità associati alla statistica del test di Kruskal-Wallis (che ha la stessa distribuzione del χ^2 con k-1 gradi di libertà, dove k è il numero di gruppi a confronto). In quasi tutti i casi è possibile respingere l'ipotesi nulla secondo cui i gruppi provengono dalla medesima popolazione statistica con una probabilità di commettere un errore del primo tipo inferiore al 5%. Solo in 5 dei 36 confronti effettuati non è possibile respingere l'ipotesi nulla ($\alpha = 0,05$).

Nell'analisi delle componenti principali, le prime due componenti principali sono sufficienti per descrivere il 75,36% della varianza e precisamente l'asse 1 ne condensa il 53,69%, mentre l'asse 2 il 21,67%. Nel diagramma congiunto delle variabili e degli oggetti costruito con la tecnica del biplot e basato sulle prime due componenti principali (Fig. 2), il vettore-variabile FPUA_Settembre28 è quasi parallelo al primo asse, mentre i vettori-variabile FPUA_Novembre e FPUA_Settembre01 hanno approssimativamente la stessa direzione del secondo asse.

Tab. 2: Matrice con i valori di probabilità associati alla statistica del test di Kruskal-Wallis.
Tab. 2: Matrika verjetnih vrednosti Kruskal-Wallisovega testa.

	FPUA_AP	FPUA_MA	FPUA_LU	FPUA_AG07	FPUA_AG28	FPUA_SE01	FPUA_SE28	FPUA_OT	FPUA_NO
FPUA_AP	0	8,05E-64	41,65E-29	1,05E-85	4,18E-81	1,72E-57	5,04E-42	1,45E-53	1,23E-25
FPUA_MA		0	3,02E-08	4,02E-08	1,10E-06	0,0322	8,78E-06	1,02E-08	2,75E-13
FPUA_LU			0	7,58E-26	3,26E-23	1,05E-12	0,1911	0,4528	0,0979
FPUA_AG07				0	0,5538	0,002954	4,60E-22	5,72E-33	4,24E-37
FPUA_AG28					0	0,01599	1,57E-19	1,81E-29	7,67E-34
FPUA_SE01						0	7,25E-10	5,94E-16	1,39E-20
FPUA_SE28							0	0,6173	0,005879
FPUA_OT								0	0,03543
FPUA_NO									0

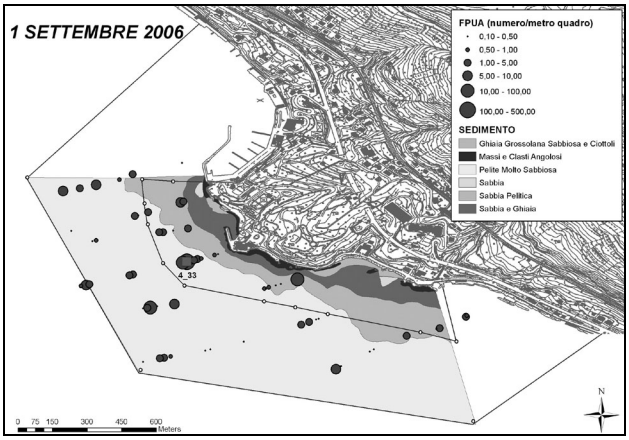

Fig. 4: Distribuzione dei valori di FPUA ottenuti dai campionamenti del 28 Settembre 2006. Le unità elementari che si separano dalle altre nel profilo della PCA sono evidenziate con un quadrato.
Sl. 4: Razporeditev vrednosti FPUA 28. septembra 2006. Osnovne enote, ločene od drugih na grafu PCA, so označene s kvadrati.

Dal diagramma è evidente che alcuni punti si separano dalla gran parte dei punti, concentrata intorno all'origine del sistema di coordinate. Essi rappresentano unità elementari caratterizzate da valori molto più elevati di densità ittica rispetto alle altre e possono essere raggruppati in tre gruppi in base alla loro posizione rispetto ai vettori-variabile: (1) le unità elementari 1 e 2 del settimo transetto e la 40 del quarto si distinguono per i valori di densità ittica rilevati nei campionamenti del 28 Settembre, (2) le unità elementari 47 e 48 del secondo transetto, la 11 del quinto transetto e la 15 del primo per i valori di densità ittica di Novembre, e (3) l'unità elementare 33 del quarto transetto per il valore rilevato il primo Settembre. I valori di densità ittica di queste unità elementari sono riportati in Tabella 3.

L'analisi degli ecogrammi corrispondenti a tali unità elementari ha evidenziato in alcuni casi importanti caratteristiche del substrato. Nel quarto transetto del primo Settembre è chiaramente visibile un grosso banco di pesce tra i 10 e i 15 m di profondità, situato per la maggior parte nell'unità elementare 33 (con densità ittica di 337,62 pesci/m^2). Il banco si trova al di sopra di una struttura sommersa che nell'ecogramma si innalza dal fondale per circa 2 m (Fig. 6). Tale struttura corrisponde alla barriera artificiale localizzata nella AMP di Miramare. Il profilo della barriera è visibile anche negli ecogrammi del quarto transetto di Luglio e del 28 Settembre (in cui si colloca l'unità elementare 40, con densità ittica di 179,28 pesci/m^2, che nella PCA si separava dalle altre EDSU) (Figg. 7, 8).

Tab. 3: Valori di FPUA delle unità elementari che si separano dalle altre nel profilo della PCA.
Tab. 3: Vrednosti FPUA osnovnih enot, ločenih od drugih na PCA grafu.

Transetto	Unità elementare	Campionamento	FPUA (pesci/m^2)
1	15	Novembre	86,94
2	47	Novembre	135,35
2	48	Novembre	302,63
4	33	1 Settembre	337,62
4	40	28 Settembre	179,28
5	11	Novembre	108,33
7	1	28 Settembre	301,71
7	2	28 Settembre	454,55

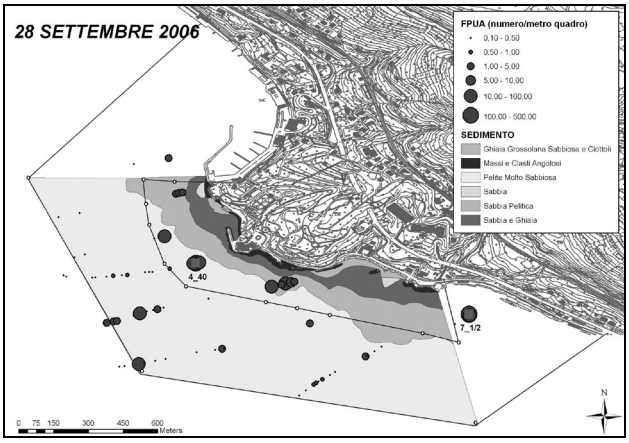

Fig. 5: Diagramma congiunto delle variabili (FPUA dei diversi periodi di campionamento) e degli oggetti (EDSU). Le variabili sono raffigurate con vettori, gli oggetti con simboli in base al transetto di appartenenza. Per alcuni oggetti è indicato il numero dell'unità elementare che rappresentano, preceduto dal numero del transetto.
Sl. 5: Ordinacijski diagram spremenljivk (FPUA iz različnih vzorčevalnih obdobij) in objektov (EDSU). Spremenljivke so prikazane z vektorji, objekti pa z različnimi simboli – v skladu s transekti, katerim pripadajo. Za nekatere objekte so podane številke transekta in EDSU.

L'analisi dell'ecogramma del quinto transetto di Novembre ha permesso di individuare un'altra peculiarità del fondale. Nell'unità elementare 11 (con densità ittica di 108,33 pesci/m^2) si osserva un banco compatto di pesce vicino al fondo, tra i 10 e i 12 m di profondità. A una distanza di circa 20–30 m da questo si trova una struttura sommersa che in fase di pre-analisi non è stata identificata come un banco di pesce per la forza dell'eco riflessa e per la forma (Fig. 9). Tale conclusione è stata avallata dal ritrovamento di una struttura dalla forma e riflessione acustica simili negli ecogrammi del quinto transetto relativi ai campionamenti del 7 e del 28 Agosto. Si tratta infatti del FAD situato all'interno della zona a protezione integrale della AMP.

L'analisi degli ecogrammi di Novembre relativi alle unità elementari 47 e 48 del secondo transetto (con densità ittica rispettivamente di 135,35 e 302,63 pesci/m^2) e 15 del primo transetto (con densità ittica di 86,94 pesci/m^2) non ha messo in evidenza particolari strutture del substrato. In corrispondenza delle suddette unità elementari, posizionate rispettivamente vicino al confine settentrionale della AMP e vicino al porticciolo di Grignano, si osservano banchi di pesce particolarmente compatti distanti un paio di metri dal fondale.

L'ecogramma del settimo transetto del 28 Settembre (Fig. 10) mostra un grosso banco di pesce a contatto con il fondo in corrispondenza delle unità elementari 1 e 2 (con densità ittica rispettivamente di 301,71 e 454,55 pesci/m^2), localizzate in prossimità del molo Sticco. Anche in questo caso, non sono evidenti particolari strutture emergenti dal substrato.

Per capire se le aree in cui si sono identificate le maggiori concentrazioni di pesce potessero essere considerate come zone di aggregazione durante tutto il periodo di campionamento, si è scelto di considerare, per ognuna delle 9 serie di dati, i valori di densità compresi in un intorno centrato sulle coordinate di latitudine e longitudine delle EDSU con i massimi valori di FPUA. Non bisogna infatti dimenticare che i dati misurati rappresentano la "fotografia acustica" di organismi in movimento, la cui posizione può variare molto in brevi intervalli di tempo. E' ragionevole perciò considerare un intorno delle EDSU caratterizzate dagli elevati valori di FPUA, che si è scelto arbitrariamente di circa 40–50 m di raggio. I valori di densità di ciascun campionamento rilevati nelle unità elementari comprese in tali intorni sono riportati nelle tabelle seguenti (Tab. 4–8).

Tab. 4: Valori di FPUA delle unità elementari corrispondenti alla zona della barriera.
Tab. 4: Vrednosti FPUA osnovnih enot v pasu grebenov.

FPUA_AP	FPUA_MA	FPUA_LU	FPUA_AG07	FPUA_AG28	FPUA_SE01	FPUA_SE28	FPUA_OT	FPUA_NO
0,71	0,00	7,43	0,00	0,00	0,00	0,00	0,02	6,24
0,23	0,17	0,00	0,00	0,00	0,02	0,01	0,06	5,65
0,14	0,03	0,00	0,00	0,00	0,00	0,14	0,01	0,01
0,12	0,00	0,86	0,00	0,00	100,38	14,98	3,12	0,02
0,03	0,00	3,08	8,18	8,32	337,62	179,28	0,04	0,01
0,07	0,00	26,49	0,00	0,00	4,09	27,67	0,00	0,00
0,00	0,00	19,08	0,00	0,00	2,81	0,00	0,00	0,00
0,03	0,00	0,02	0,00	0,00	3,41	0,01	0,00	0,00
0,13	0,00	0,03	0,00	0,00	0,74	0,00	0,03	1,21

Tab. 5: Valori di FPUA delle unità elementari corrispondenti alla zona del FAD.
Tab. 5: Vrednosti FPUA osnovnih enot v pasu FAD.

FPUA_AP	FPUA_MA	FPUA_LU	FPUA_AG07	FPUA_AG28	FPUA_SE01	FPUA_SE28	FPUA_OT	FPUA_NO
0,07	0,00	0,00	0,00	0,00	0,00	2,16	0,00	18,10
0,87	0,23	0,00	0,00	0,00	54,24	6,86	7,89	0,01
1,57	0,00	0,00	0,00	0,00	0,00	0,00	59,06	0,00
0,12	0,00	0,01	0,00	0,00	0,00	20,22	87,82	0,00
0,12	0,00	0,00	0,00	0,00	0,00	2,59	0,01	108,33
0,25	0,00	0,00	0,00	0,00	0,00	0,00	1,59	27,83
0,18	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00
0,02	0,00	0,00	0,00	0,01	0,12	15,98	0,01	0,00
0,16	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Tab. 6: Valori di FPUA delle unità elementari corrispondenti alla zona al confine settentrionale della AMP.
Tab. 6: Vrednosti FPUA osnovnih enot na severni meji osrednjega pasu AMP.

FPUA_AP	FPUA_MA	FPUA_LU	FPUA_AG07	FPUA_AG28	FPUA_SE01	FPUA_SE28	FPUA_OT	FPUA_NO
1,53	0,00	3,43	19,17	19,32	0,04	3,78	0,93	0,00
0,89	0,00	0,08	0,00	0,00	0,00	3,33	0,46	0,00
1,43	0,00	10,65	0,00	0,00	6,23	1,92	0,00	2,58
1,27	0,00	10,99	0,00	0,00	1,14	0,00	0,22	0,00
0,51	0,00	0,22	0,00	0,00	0,00	0,00	5,22	135,35
0,08	0,00	0,67	0,00	0,00	0,01	0,00	0,00	302,63

Tab. 7: Valori di FPUA delle unità elementari corrispondenti alla zona vicino al porticciolo di Grignano.
Tab. 7: Vrednosti FPUA osnovnih enot v pasu blizu pristanišča Grignano.

FPUA_AP	FPUA_MA	FPUA_LU	FPUA_AG07	FPUA_AG28	FPUA_SE01	FPUA_SE28	FPUA_OT	FPUA_NO
0,25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,15	0,00	0,00	0,00	1,06	0,00	0,01	0,00	0,00
0,11	0,00	0,05	0,00	0,00	0,00	0,00	3,61	0,00
0,19	19,51	0,02	0,00	0,00	0,00	0,00	0,08	0,00
0,09	0,00	0,00	0,00	0,00	0,00	0,00	0,03	86,94
0,12	0,00	0,00	0,00	0,00	0,00	3,93	0,00	0,00
0,30	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00
0,45	0,00	0,01	0,03	0,03	0,00	0,00	0,10	0,10
0,34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	11,92

Tab. 8: Valori di FPUA delle unità elementari corrispondenti alla zona del molo Sticco.
Tab. 8: Vrednosti FPUA osnovnih enot v pasu pomola Sticco.

FPUA_AP	FPUA_MA	FPUA_LU	FPUA_AG07	FPUA_AG28	FPUA_SE01	FPUA_SE28	FPUA_OT	FPUA_NO
0,18	0,00	0,00	0,00	0,00	0,00	301,71	0,00	0,00
0,10	0,00	0,00	0,00	0,00	0,00	454,55	0,00	0,00
0,07	0,00	0,00	0,00	0,00	0,00	24,82	0,00	0,35
0,68	0,00	0,00	0,00	0,00	0,88	0,00	0,00	0,00
0,47	0,00	0,00	0,00	0,00	1,36	0,00	0,00	0,00
0,40	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Dal confronto delle tabelle risulta che nell'arco del periodo di campionamento sono stati rilevati elevati valori di FPUA con frequenza maggiore nelle zone della barriera, del FAD e al confine settentrionale della AMP rispetto alle altre due zone considerate. Valori di FPUA maggiori di 10 pesci/m^2 sono stati osservati rispettivamente in 3 (zona della barriera) e in 4 (zona del FAD e zona al confine settentrionale della AMP) dei 9 campionamenti. Nella zona del molo Sticco e nella zona vicina al porticciolo di Grignano, valori così elevati sono stati rilevati solo 1 e 2 volte rispettivamente.

DISCUSSIONE E CONCLUSIONI

Lo studio condotto ha permesso di evidenziare alcune importanti caratteristiche della distribuzione geografica della componente ittica della AMP di Miramare. I campionamenti effettuati hanno identificato le maggiori concentrazioni di pesce in 5 aree: la zona della barriera, la zona del FAD, la zona al confine setten-

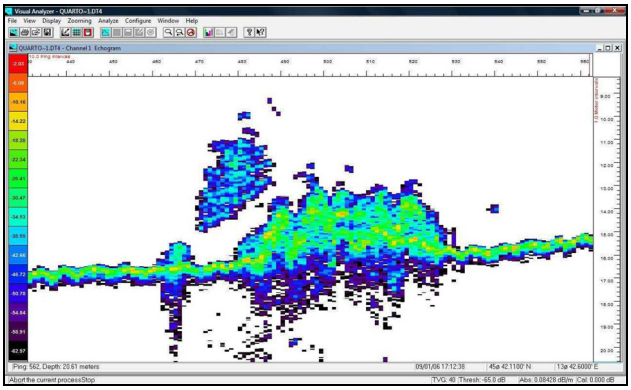

Fig. 6: Particolare dell'ecogramma relativo al quarto transetto del primo Settembre 2006 in cui si può osservare la barriera sovrastata da un banco di pesci.
Sl. 6: Detajl ehograma četrtega transekta z dne 1. septembra 2006, ki prikazuje ribjo jato nad grebenom.

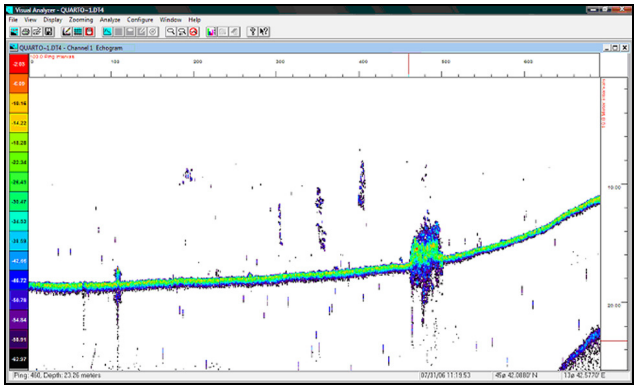

Fig. 7: Ecogramma relativo al quarto transetto di Luglio 2006.
Sl. 7: Ehogram četrtega transekta z dne 1. julija 2006.

trionale della AMP, la zona vicina al porticciolo di Grignano e la zona del molo Sticco. Dall'osservazione dei valori in Tabelle 4–8 e dal confronto visivo delle mappe sembra che la probabilità di trovare aggregazioni ittiche in prossimità della barriera, del FAD e al confine settentrionale della AMP sia maggiore rispetto agli altri siti campionati nell'area di studio. La zona vicina al porticciolo di Grignano e la zona del molo Sticco non sembrano invece costituire dei punti con un potenziale di aggregazione costante durante il periodo di campionamento.

I risultati ottenuti confermano il potenziale aggregativo di strutture artificiali quali barriere e FAD e dimostrano la validità dell'utilizzo di echosounder per lo studio dei popolamenti ittici in strutture artificiali. Sebbene tecniche acustiche attive siano state applicate con successo nel monitoraggio di piattaforme petrolifere e impianti idroelettrici (Thorne, 1994; Stanley & Wilson, 1998; Stanley & Wilson, 2000; Soldal *et al.*, 2002), pochi sono gli studi finora condotti su barriere artificiali (Thorne *et al.*, 1989; Fabi & Sala, 2002; Sala *et al.*, 2007). Dati utili alla gestione di barriere artificiali nel Mar Adriatico (Italia) provengono dagli studi idroacustici condotti da Fabi & Sala (2002) nella barriera artificiale di Senigallia. Il posizionamento di echosounder stazionari all'interno e all'esterno dell'area della barriera permise di registrare valori più elevati di biomassa ittica vicino alla struttura artificiale, mentre ad una distanza di 80 m gli effetti della barriera erano ridotti. Nel presente studio, l'acquisizione di dati è avvenuta lungo transetti mediante un echosounder in movimento e quindi la quantità di dati raccolti nell'area della barriera e del FAD è limitata. Ciò nonostante, è comunque evidente la peculiarità di queste due zone all'interno dell'area di studio.

L'importanza della barriera era già stata sottolineata da studi condotti tramite "visual census" che avevano messo a confronto la barriera artificiale della AMP e la scogliera situata al di sotto del Castello di Miramare con altri ambienti del Golfo di Trieste che, come la barriera, costituiscono siti di aggregazione ittica in aree al largo caratterizzate da substrato molle, quali il Dosso di S.ta Croce, le strutture sperimentali sotto alle mitilicolture in zona Sistiana-Villaggio del Pescatore e le piramidi presso i Filtri di Aurisina. Da tali studi risultava evidente la disparità qualitativa e quantitativa degli avvistamenti di specie ittiche effettuati nelle stazioni di Miramare con la situazione all'esterno dell'area protetta (Castellarin *et al.*, 2001). Sebbene la tecnica del "visual census" sia tra i metodi più comunemente utilizzati per la valutazione delle aggregazioni ittiche su substrati rocciosi naturali e su barriere artificiali (Charbonnel *et al.*, 1997), le condizioni ambientali e il comportamento delle diverse specie possono costituire importanti limiti: la trasparenza dell'acqua può compromettere il campionamento, mentre il comportamento di specie criptiche può ridurre la loro probabilità di incontro, portando ad una sottostima della reale abbondanza (Harmelin-Vivien *et al.*, 1985). L'utilizzo di tecniche acustiche attive rappresenta perciò un valido strumento complementare ai censimenti visivi nello studio delle barriere artificiali. In tale ottica l'echosounder potrà essere utilizzato per ottenere stime quantitative più precise della componente ittica nella barriera di ripopolamento della Riserva di Miramare e per condurre uno studio comparato delle barriere artificiali sperimentali e delle afferrature al largo presenti nel Golfo di Trieste (Odorico & Costantini, 2001).

Sebbene i monitoraggi acustici non abbiano messo in evidenza particolari caratteristiche del substrato nella zona vicino al confine settentrionale della AMP, tale area è caratterizzata da massi e rocce di modeste dimensioni (diametro inferiore a 1 m), disposti in modo eterogeneo su un fondale di sabbia e ghiaia *(pers.*

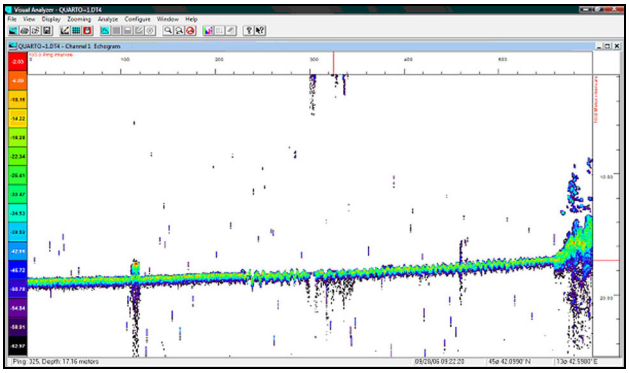

Fig. 8: Ecogramma relativo al quarto transetto del 28 Settembre 2006.
Sl. 8: Ehogram četrtega transekta z dne 28. septembra 2006.

observ.). Una gran quantità di studi dimostra che la struttura dell'habitat ha importanti conseguenze sulla distribuzione spaziale dei popolamenti ittici, sia in in ambienti rocciosi temperati (Choat & Ayling, 1987; Tupper & Boutilier, 1997; García-Charton & Pérez-Ruzafa, 2001) che tropicali (Tolimieri, 1995; Friedlander & Parrish, 1998; Holbrook *et al.*, 2000). La presenza di massi sul fondale e la vicinanza alle rocce della costa potrebbero quindi spiegare gli elevati valori di densità ittica rilevati nell'area al confine settentrionale della AMP.

Non bisogna comunque dimenticare che i dati raccolti rappresentano delle "fotografie" di una situazione puntiforme nel tempo e nello spazio. Data la brevità del periodo di campionamento, i risultati ottenuti non possono assumere carattere inferenziale, ma solo descrittivo. Per poter capire se le aree osservate siano dei punti di aggregazione ittica durante tutto l'anno o solo in determinati periodi è necessaria la raccolta di una maggior quantità di osservazioni. Lo studio sino ad ora condotto costituisce quindi un pre-survey per la pianificazione di ulteriori ricerche che potranno confermare il potenziale aggregativo delle zone della barriera, del FAD e del confine settentrionale della AMP. A tale scopo sarà utile lo studio specifico della densità ittica in tali aree target. In questa prospettiva, un importante risultato raggiunto con la presente ricerca è stata la standardizzazione di un metodo di acquisizione ed elaborazione dei dati acustici che potrà essere utilizzato come protocollo di riferimento in monitoraggi futuri, permettendo in tal modo il confronto dei dati e lo studio delle variazioni di densità ittica su scala temporale più ampia.

Poiché gli ecogrammi non forniscono sufficienti informazioni per identificare con certezza le specie sonificate, si è voluto condurre uno studio comparato delle misurazioni ricavate tramite echosounder con i dati ottenuti dai censimenti visivi. I dati di "visual census" raccolti in barriera nello stesso periodo in cui si sono svolti i campionamenti acustici mostrano valori elevati di abbondanza per cefali (Mugilidae), corvine *(Sciaena umbra)* e saraghi *(Diplodus vulgaris, D. sargus, D. puntazzo, D. annularis)* (AA.VV., 2007). Queste sono specie dalle abitudini gregarie, che vivono a limitate profondità e prediligono substrati rocciosi (ad eccezione dei cefali, che sono specie ubiquitarie). Si è perciò ipotizzato che le elevate densità rilevate in barriera fossero dovute soprattutto a cefali, corvine o saraghi. La realizzazione di censimenti visivi anche nella zona del FAD e nella zona vicino al confine settentrionale della Riserva permetterebbe di ottenere informazioni sulle specie presenti in tali aree con potenziale aggregativo. Inoltre, l'ausilio di una videocamera via cavo durante monitoraggi acustici futuri consentirà di ottenere maggiori informazioni sulle specie sonificate e sulle loro proprietà di riflessione acustica, così da facilitare il riconoscimento delle specie sulla base della tipologia dei banchi visualizzati negli ecogrammi.

Lo studio condotto ha dimostrato la validità di una metodologia di campionamento che può essere utilizzata per migliorare l'efficacia di gestione delle aree marine protette. La limitata estensione della AMP di Miramare ne facilita il controllo e la gestione rispetto ad altre aree marine protette che si estendono su superfici ben più ampie. In tale aree, l'utilizzo di tecniche acustiche attive permetterebbe di scoprire zone di aggregazione ittica che dovrebbero essere maggiormente tutelate dall'impatto antropico. Il posizionamento di campi ormeggio e ancoraggio, la creazione di zone interdette alla navigazione e la gestione del turismo e delle visite subacquee dovrebbero tener conto delle zone individuate. Le aree di aggregazione ittica, inoltre, costituendo potenziali aree di interesse per i pescatori, potrebbero rappresentare importanti punti di riferimento nella pianificazione delle strategie di controllo e sorveglianza all'interno di una AMP.

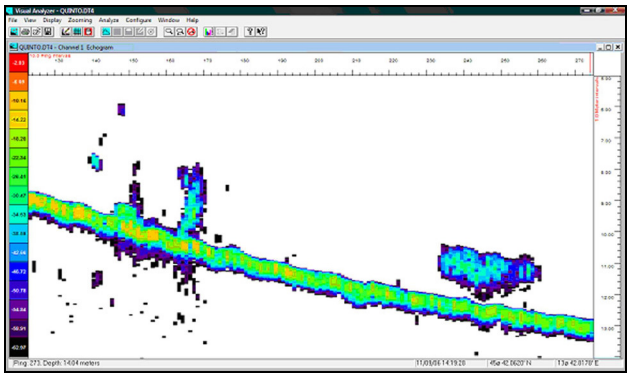

Fig. 9: Particolare dell'ecogramma relativo al quinto transetto di Novembre 2006. Sulla destra si osserva un banco di pesci, separati dal fondale, sulla sinistra la struttura del FAD.
Sl. 9: Detajl ehograma petega transekta iz novembra 2006, ki prikazuje ribjo jato (na desni) in profil FAD (na levi).

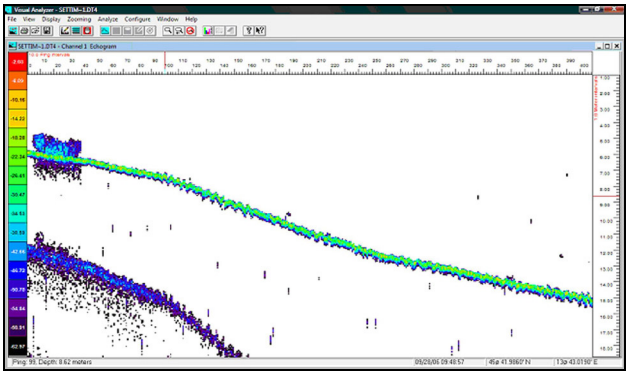

Fig. 10: Ecogramma relativo al settimo transetto del 28 Settembre 2006.
Sl. 10: Ehogram sedmega transekta z dne 28. septembra 2006.

Infine, la valutazione dell'efficacia ed efficienza della gestione delle aree protette in termini di impatti positivi o negativi che essa produce è un argomento molto sentito presso la AMP di Miramare che da anni è sito di sperimentazione della valutazione dell'efficacia all'interno di un progetto internazionale di applicazione delle linee guida del manuale IUCN NOAA WWF intitolato "How is your MPA doing – a guidebook of natural and social indicators for evaluating Marine Protected Areas Management Effectiveness" (Pomeroy *et al.*, 2004). Indici ed indicatori di misura del risultato delle azioni di gestione sono numerosi, ma vanno in ogni caso riferiti e adattati alla realtà in cui si opera. L'uso dell'echosounder per la valutazione dei popolamenti ittici all'interno dell'area protetta, grazie alla rapidità nell'acquisizione dati e alla possibilità di coprire ampie zone, e la definizione di un protocollo di analisi e interpretazione dei dati raccolti si inseriscono perfettamente quali strumenti a supporto della misurazione di alcuni indicatori biofisici dell'efficacia legati alla componente ittica.

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ANALIZA BIOAKUSTIČNIH PODATKOV PRIDOBLJENIH Z EHOSONDERJEM ZA OCENO RIBJIH POPULACIJ V NARAVNEM MORSKEM REZERVATU MIRAMARE

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POVZETEK

Akustične metode so neinvazivne in zato predstavljajo primerno orodje za dopolnitev opazovalnih cenzusov ("visual census") pri raziskavah in monitoringu ribjih populacij znotraj zavarovanih morskih območij. Med aprilom in novembrom 2006 so avtorji raziskovali prostorsko razporeditev ribjih populacij znotraj Naravnega morskega rezervata Miramare (Tržaški zaliv, severni Jadran), z uporabo znanstvenega ehosonderja split-beam. Tako so bili ugotovljeni potencialni predeli, kjer se ribe združujejo. Na predelu ob grebenu, FAD-a (fish aggregating device) in severne meje rezervata, je bila v vzorčevalnem obdobju ugotovljena visoka gostota ribjih populacij. Pridobljeni rezultati predstavljajo pomembno informacijo za upravljanje in oceno učinkovitosti upravljanja zavarovanega morskega rezervata.

Ključne besede: Naravni morski rezervat Miramare, ribja gostota, ehosonder

BIBLIOGRAFIA

AA.VV. (1999): Fish visual census in Marine Protected Areas. Proceeding of the International Workshop, Ustica, Italy, 26–28 June 1997. Naturalista Sicil., XXIII (suppl.), 1–293.

AA.VV. (2004): User Guide Visual Analyzer 4. Bio-Sonics Inc., Seattle (WA).

AA.VV. (2007): Valutazione dell'impatto delle attività subacquee. Relazione interna. WWF Italia – Riserva Naturale Marina di Miramare, Trieste.

Castellarin, C., G. Visintin & R. Odorico (2001): L'ittiofauna della Riserva Naturale Marina di Miramare (Golfo di Trieste, Alto Adriatico). Annales, Ser. Hist. Nat., 11(2), 207–216.

Charbonnel, E., P. Francour & J. G. Harmelin (1997): Finfish populations assessment techniques on artificial reefs: a review in the European Union, in European Artificial Reef Research. Southampton Oceanography Center, Jensen, AC., pp. 261–277.

Choat, J. H. & A. M. Ayling (1987): The relationship between habitat structure and fish faunas on New Zealand reefs. J. Exp. Mar. Biol. Ecol., 110, 257– 284.

Costantini, M., E. Vinzi, M. Trazzi, V. Martinelli, S. Ciriaco & M. Spoto (2004): Distribuzione spazio temporale dei banchi di pesce nella WWF – Riserva Naturale Marina di Miramare: anni 2003–2004. Hydrores Information, 26, 14–20.

Fabi, G. & A. Sala (2002): An assessment of biomass and diel activity of fish at an artificial reef (Adriatic sea) using a stationary hydroacoustic technique. ICES J. Mar. Sci., 59, 411–420.

Friedlander, A. M. & J. D. Parrish (1998): Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. J. Exp. Mar. Biol. Ecol., 224, 1–30.

García-Charton, J. A. & A. Pérez-Ruzafa (2001): Spatial pattern and the habitat structure of a Mediterranean reef fish local assemblage. Mar. Biol., 138, 917–934.

Hammer, Ø., D. A. T. Harper & P. D. Ryan (2001): PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontol. Electronica, 4(1).
http://palaeoelectronica.org/2001_1/past/issue1_01.htm

Hammer, Ø., D. A. T. Harper & P. D. Ryan (2008): PAST – PAlaeontological STatistics, ver. 1.76 Users guide. http://folk.uio.no/ohammer/past/ (2008–01)

Harmelin-Vivien, M. L., J. G. Harmelin, C. Chauvet, C. Duval, R. Galzin, P. Lejeune, G. Barnabé, F. Blanc, R. Chevalier, J. Duclerc & G. Lasserre (1985): Evaluation visuelle des peuplements et populations de poissons: Méthodes et problémes. Rev. Ecol. Terre & Vie, 40, 467–539.

Holbrook, S. J., G. E. Forrester & R. J. Schmitt (2000): Spatial patterns in abundance of a damselfish reflect availability of suitable habitat. Oecologia, 122, 109–120.

MacLennan, D. N. (1990): Acoustical measurement of fish abundance. J. Acoust. Soc. Am., 87, 1–15.

MacLennan, D. N. & J. Simmonds (1992): Fisheries Acoustics. Chapman & Hall, London, 325 p.

Misund, O. A. (1997): Underwater acoustics in marine fisheries and fisheries research. Rev. Fish Biol. Fish., 7, 1–34.

Odorico, R. (1997): Studio preliminare per la messa in opera di un sistema di aggregazione di specie ittiche mediante Strutture Artificiali Leggere (SAL). Relazione interna. WWF – Riserva Naturale Marina di Miramare, Trieste.

Odorico, R. & M. Costantini (2001): Linea 2.a.12: Valutazione della pescosità in zone ad elevata aggregazione ittica. Shoreline Soc. Coop. per Azienda Speciale Aries – CCIAA di Trieste, progetto Pilota sulla gestione delle zone di pesca. L.R. 11/98. WWF Italia – Riserva Naturale Marina di Miramare, Trieste.

Odorico, R. & S. Ciriaco (2004): Realizzazione di un progetto di sperimentazione sulla "valutazione e allocazione delle risorse alieutiche" (linea d'azione 5). Progetto di valorizzazione dei risultati del programma Pesca ed avvio di forme di sviluppo integrato del settore alieutica del Golfo di Trieste" (ARIES PESCA 2000–2003) finanziato nell'ambito della Misura 4.4 del Programma operativo regionale SFOP 2000–2006. WWF Italia – Riserva Naturale Marina di Miramare, Trieste.

Pomeroy, R. S., J. E. Parks & L. M. Watson (2004): How is your MPA doing? A guidebook of natural and social indicators for evaluating Marine Protected Area Management Effectiveness. IUCN, Gland, Switzerland and Cambridge, UK.

Sala, A., G. Fabi & S. Manoukian (2007): Vertical diel dynamic of fish assemblage associated with an artificial reef (Northern Adriatic Sea). Sci. Mar., 71(2), 355–364.

Soldal, A. V., I. Svellingen, T. Jorgensen & S. Lokkeborg (2002): Rigs-to-reefs in the North Sea: hydroacoustic quantification of fish in the vicinity of a "semi-cold" platform. ICES J. Mar. Sci., 59, 281–287.

Stanley, D. R. & C. A. Wilson (1998): Spatial variation in fish density at three petroleum platforms as measured with dualbeam hydroacoustics. Gulf Mex. Sci., 1, 73–82.

Stanley, D. R. & C. A. Wilson (2000): Variation in the density and species composition of fishes associated with three petroleum platforms using dual beam hydroacoustics. Fish. Res., 47, 161–172.

Tempesta, M., R. Treleani, C. Ceschia & G. Orel (1996): Proposta di mappatura dei fondi mobili della Riserva marina di Miramare tramite lo studio del macrozoobenthos. Hydrores, Anno XIII, 14, 57–62.

Thorne, R. E. (1994): Hydroacustic remote sensing for artificial habitat. Bull. Mar. Sci., 55, 897–901.

Thorne, R. E., J. B. Hedgepath & J. Campos (1989): Hydroacoustic observations of fish abundance and behavior around an artificial reef in Costa Rica. Bull. Mar. Sci., 44(2), 1071–1989.

Tolimieri, N. (1995): Effects of microhabitat characteristics on the settlement and recruitment of a coral reef fish at two spatial scales. Oecologia, 102, 52–63.

Tupper, M. & R. G. Boutilier (1997): Effects of habitat on settlement, growth, predation risk and survival of a temperate reef fish. Mar. Ecol. Prog. Ser., 151, 225–236.

Vacchi, M. & G. La Mesa (1999): Fish visual census in Italian Marine Protected Area: experience and perspectives. Naturalista Sicil., XXIII (suppl.), 105–121.

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EVIDENCE FOR SEAGRASS COMPETITION IN A CENTRAL CROATIAN ADRIATIC LAGOON

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ABSTRACT

Evidence for competition between two co-occurring seagrass species, Zostera noltii *and* Z. marina*, was found along an isobath transect in the Novigrad Sea, Central Croatian Adriatic. The transect included developed (marina) and undeveloped regions of shoreline. Each species' coverage and presence was evaluated using DGPS-tracked underwater videography. Seagrass shoot density was estimated from SCUBA samples. The two* Zostera *species exhibited opposite significant changes correlated with the environmental gradient:* Z. marina *cover and shoot density decreased while* Z. noltii *cover and shoot density increased with distance from marina. Significantly more of the spatial variation was explained by species interaction than by environmental variables. We conclude that competition is a major process structuring the distribution of* Zostera *species in the Novigrad Sea.*

Key words: *Zostera*, seagrass competition, environmental gradient, DGPS-supported videography, Adriatic

EVIDENZA DI COMPETIZIONE TRA FANEROGAME MARINE NELLA LAGUNA DELL'ADRIATICO CENTRALE (CROAZIA)

SINTESI

L'articolo tratta la competizione esistente fra due specie di fanerogame marine, Zostera noltii *e* Z. marina*, che coabitano nel mare di Novigrad (Adriatico centrale). Il transetto, effettuato lungo un'isobata, ha compreso zone sviluppate (marina) e non sviluppate della costa. La presenza e la copertura di ogni specie sono state valutate con l'aiuto della videografia subacquea sostenuta da DGPS. La densità dei ciuffi è stata calcolata dai campioni raccolti durante l'immersione. Per le due specie di* Zostera *sono state riscontrate variazioni significanti opposte correlate con il gradiente ambientale. La copertura e la densità dei ciuffi di* Z. marina *diminuiscono, mentre la copertura e la densità dei ciuffi di* Z. noltii *aumentano con la distanza dalla marina. La variazione nello spazio delle specie è stata significativamente chiarita meglio considerando l'interazione fra le specie che le variabili ambientali. Gli autori sostengono che la competizione sia il fattore principale che influenza la distribuzione delle specie di* Zostera *nel mare di Novigrad.*

Parole chiave: *Zostera*, competizione tra fanerogame marine, gradiente ambientale, videografia sostenuta da DGPS, Adriatico

INTRODUCTION

Much information is available on the spatial distribution of seagrasses as a result of the interplay between seagrass and the physical environment, such as light attenuation (reviewed by Leoni *et al.*, 2008), nutrient concentrations (reviewed by Touchette & Burkholder, 2000), sediment grain size and organic content (reviewed by de Boer, 2007), salinity (reviewed by Touchette, 2007), temperature (reviewed by Lee *et al.*, 2007), wave exposure (reviewed by Cabaço *et al.*, 2008), air exposure during low tides, benthic slope, and depth. These responses are interpreted as an outcome of physiological tradeoffs during the process of adaptation to these physical conditions and resources. Fewer studies have incorporated both physical and biological processes, such as competition and their effect on spatial distribution and abundance (Fourqurean *et al.*, 1995; Laugier *et al.*, 1999; Tanaka & Kayanne, 2007), and seemingly none have done so within a single analysis.

Our study focuses on two co-occurring *Zostera* species, *Z. noltii* and *Z. marina*, along a 3-m isobath transect spanning a developed area (residential and tourist housing, light commercial business, seawall, marina, agricultural fields), to an undeveloped shoreline. The restriction to the 3-m isobath ensured that (i) neither species was investigated at its lower or upper depth limit (depth distribution for both species ranges from 0.25-4.5 m in the study area; Schultz *et al.*, 2009), that (ii) depth related variation in physical environmental variables was ignored, and (iii) that the two species were co-occurring within most of the study transect and associated plots. This gave us the opportunity to investigate spatial variation of the two species in relation both to physical environmental gradients along the transect and to each other's presence.

Much is known about the two *Zostera* species, although the majority of studies have been carried out outside the Adriatic and even the Mediterranean. In the Adriatic, *Z. noltii* is described as a widely distributed species mainly found in the shallow benthos of a range of habitats from sheltered low energy to higher energy environments with more wave and current activity (Widdows *et al.*, 2008). *Z. marina* in the Adriatic is described as the species with the more restricted and irregular distribution, requiring sheltered places and freshwater input (Guidetti, 2000). Although *Z. noltii* is considered the more marine species, both species are known to have great euryhalinity tolerance (den Hartog, 1970) and both have been found to benefit from decreased salinities (Hootsmans *et al.*, 1987; Vermaat *et al.*, 2000; Charpentier *et al.*, 2005). *Z. noltii* appears to prefer sandy sediments, whereas *Z. marina* tends to be found on muddier ground with a higher organic content (Duarte & Kalff, 1988; Caniglia *et al.*, 1992; Koch, 2001). *Z. marina* as the larger species is expected to be more tolerant of low light conditions, *e.g.* as a consequence of sediment re-suspension, as it has greater light-absorbing surface area and higher resource-storing volume. Both species have been shown to respond positively to addition of ammonium and nitrate in N-limited environments (Marba *et al.*, 1996), a situation that can be expected near residential areas and freshwater inflow.

The placement of the transect within the study area offered (i) significant variation in physical environmental variables, including salinity, wave exposure, sediment characteristics, distance from anthropogenic influence and freshwater due to the change in geographical location (without depth interference), and (ii) an opportunity to investigate the two *Zostera* species within a continuous mixed bed. This allowed us to compare the relative importance of the physical environment and species interactions for each species' spatial distribution.

MATERIALS AND METHODS

Study area

The Novigrad Sea, Croatia (44°12'N, 15°30'E), is a protected estuarine embayment of 29 km^2 (approximately 8 × 5 km at longest axes) in the eastern Adriatic Sea (Fig. 1). It is connected to the Velebit Channel in the north by a narrow strait (the Maslenica Channel), and is receiving freshwater inflow from the Zrmanja River in the northeast, by underground springs, a few small seasonal creeks, and a canal draining water from the agricultural area near the town of Posedarje (Sinovčić *et al.*, 2004; Figs. 1 and 2). Benthic habitats include dense macroalgae/rock, unconsolidated bare sediments (gravel, sand, and mud) and sparse to dense seagrass belonging to three species *Zostera noltii*, *Z. marina*, and *Cymodocea nodosa*. The present study was carried out in spring 2007 (salinity measurements in fall and winter) in the low gradient westernmost portion of the Novigrad Sea where the seagrass cover is a continuous meadow extending from the developed north side of the bay (town of Posedarje) to the undeveloped south side (Fig. 2). Here the water is shallower than 5 m and the bottom is muddy to sandy.

DGPS/videography and video analysis

Along a constant depth (3-m isobath) transect of 1167 m length, a video sensor (Sony, 480 colour TVL) continuously recorded the sea bottom. Simultaneously overlaid on the video image was the satellite time recorded every two seconds. Depth was monitored by a 200 KHz, 11°, single-beam transducer. Horizontal DGPS coordinates were taken with real-time submeter accuracy from radio beacon transmissions to a GPS antenna held by kayak operator directly above the video sensor visible from the surface (Norris *et al.*, 1997;

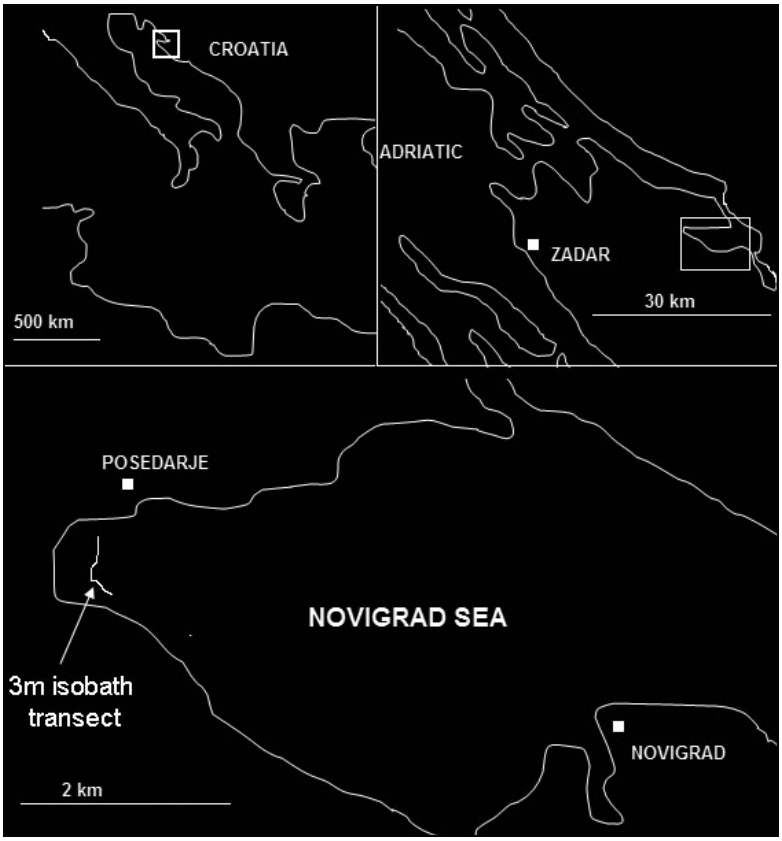

Fig. 1: Approximate location of the 3 m isobath transect at the Novigrad Sea, Croatia.
Sl. 1: Približna lokacija trimetrskega izobatnega transekta v Novigrajskem morju, Hrvaška.

Dauwalter *et al.*, 2006; Schultz, 2008). Subsequent analysis of every second of the recorded video allowed for calculation of the linear coverage for all seagrass species present.

Seagrass and sediment sampling and processing

Following over the DGPS tracks of the video transect by submeter real-time navigation, a SCUBA diver was led to 32 stations evenly spaced along the previously followed video transect. At each station, the diver harvested all seagrass from three replicate circular plots of 0.085 m^2 each, as well as 3 sediment cores (100 ml syringes with stopper) of 3 cm diameter inserted into the bottom to a depth of approximately 8–10 cm. Seagrass and sediment samples were kept refrigerated. Seagrass was processed within 48 hours, sediment within 6 hrs. The uppermost 5 cm of sediment were placed in plastic containers, homogenized by stirring and kept air tight and refrigerated until further processing (within 72 hours), when a portion of the sediment (approximately 30 g) was wet-weighed and then dried at 60ºC until constant dry weight. Water content of the sediment was calculated as the weight loss in percent. Loss-on-ignition (LOI) analysis was used to measure the sediment organic matter content. Small samples of sediment (mean weight 9 g) were dried overnight at 105ºC until weight constancy and then combusted at 530ºC for 2 h. Organic content was calculated as the weight loss in percent. In seagrass samples from each of the 3 plots at each of the 32 stations the shoots of all species present *(Z. marina, Z. noltii, Cymodocea nodosa)* were counted. Ten shoots (or less if less available in the sample) from each species were randomly chosen and the length (ruler) and width (dissecting scope) of the longest intact leaf of each shoot was measured and the leaf area calculated.

Salinity, bottom slope, and wave exposure

Water samples were taken from the surface and salinity immediately measured with a refractometer. All samples were taken from a kayak and approximately every 10 m while tracking the 3-m isobath transect with submeter accuracy. Bottom slope was calculated from the shortest distance between the 2 m isobath line and the 4 m isobath line passing through each of the 32 sampling stations on the 3-m isobath line. All isobath lines were identified by kayak-based DGPS tracking with the depth continuously monitored as described above. Depth-dependent wave exposure (REI_d) was calculated

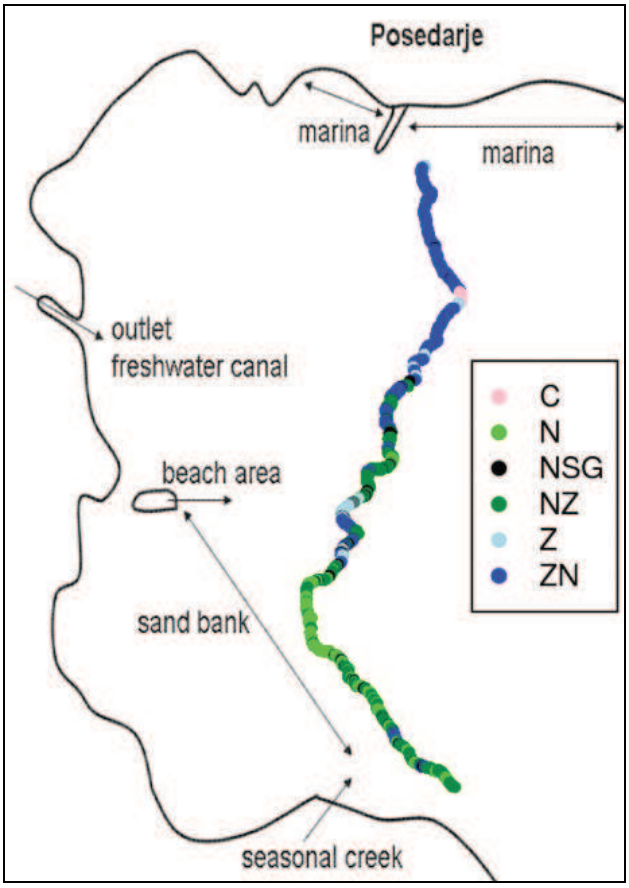

Fig. 2: Detailed view of the 1,167 m long 3 m isobath transect in the westernmost section of the Novigrad Sea, Croatia. Colour code identifies seagrass species and relative visual presence for individual units of approximately 0.3 m. Legend: C = *Cymodocea nodosa*, ***N =*** *Zostera noltii*, ***Z =*** *Zostera marina*, ***NZ = mixed*** *Zostera* ***with*** *Z. marina* ***observed within a 0.3 m unit but not in every video frame, ZN = mixed bed with*** *Z. marina* ***present in every video frame, NSG = no seagrass (unconsolidated sediments).***
Sl. 2: Podroben prikaz 1.167 m dolgega in 3 m širokega izobatnega transekta v najzahodnejšem delu Novigrajskega morja na Hrvaškem. Vrsti sta označeni z različnima barvama v posameznih približno 0,3 m velikih enotah. Legenda: C = *Cymodocea nodosa*, ***N =*** *Zostera noltii*, ***Z =*** *Zostera marina*, ***NZ = obe vrsti, pri čemer se*** *Z. marina* ***pojavlja v 0,3 m veliki enoti, vendar ne v vsakem video-okvirju. NSG = brez morskih trav (nestrjene usedline).***

using the formulas given in Krause-Jensen *et al.* (2003). Necessary data on wind direction, velocity and frequency were provided by the Croatian Meteorological and Hydrological Service. Fetch distances were measured as the distance between a sampling point and the nearest shoreline in each of eight compass directions (N, NW, W, SW, S, SE, E, NE) as measured on satellite photos with resolution 2.5 m per pixel (Google Earth 5.0, 2009).

Data analysis

Effects of physical variables on shoot densities were tested with single- and multiple-factor analysis of variance (ANOVA) on untransformed response variables, which were not significantly different from those normally distributed. Significance of individual coefficients in the ANOVA multiple-factor was evaluated with t-tests. F-test was used to compare the results of two nested analyses of variance that differed only in the presence or absence of seagrass shoot density. Relationships among variables were visualized with a standard biplot of the results of principal components analysis based on correlations among all variables.

RESULTS

Seagrass visual cover along the transect

Along the 1,167 m transect, three seagrass species were observed (Fig. 2). *Z. noltii* was present over 974 m (83.5% of the transect), *Z. marina* over 877 m (75.1%) and *C. nodosa* over 17 m (1.5%). *C. nodosa* was restricted to one small section of the transect. The *Zostera* species mostly co-occurred in mixed communities (781 m linear coverage, 66.9% of the transect). Near the marina development, *Z. marina* had greater visual presence and *Z. marina* blades were frequent and observed in every video frame (Fig. 2: "ZN", coded dark blue). Further away from the marina, fewer blades of *Z. marina* were observed within the *Z. noltii*-dominated seagrass bed *(Z. marina* present within each base unit of approximately 0.3 m which equals one second of video, but not in every video frame (Fig. 2: "NZ", coded dark green). Monospecific patches of *Z. marina* (Fig. 2: "Z", coded light blue, 96 m accumulative coverage, 8.2% of the transect) were generally rare and occurred either near the marina or along a heavily frequented beach area (Fig. 2). Monospecific patches of *Z. noltii* (Fig. 2: "N", coded light green, total coverage 193 m, 16.5%) were twice as common as those of *Z. marina*, but basically restricted to the natural side, where they were most expansive along the sand bank (Fig. 2) located in the southwest of the study area. *Z. marina* visual presence increased again (Fig. 2 shift from "NZ" to "ZN") in the area directly influenced by a seasonal creek at the very south end of the transect (Fig. 2).

Tab. 1: Description of the general environment along the transect. For references with geographical locations refer to figure 2.
Tab. 1: Opis okolja vzdolž transekta. Glede podrobnosti o geografskih lokacijah na preučevanem območju glej sliko 2.

Geographical location	Description of the environment
North	Transect located within the marina, a concreted area that experiences regular small boat traffic and mooring, as well as freshwater drainage and wastewater input.
Northwest	Near transect enters a freshwater canal, which receives drainage from agricultural fields and some residential waste water. The mouth of the canal is characterized by dense growth of marsh plants, such as *Phragmites* spp.
West	Transect near a low-gradient shallow beach area experiencing frequent bathing and boating/anchoring traffic from May to October.
Southwest	Transect follows the edge of a shallow sand bank, an area where the benthic slope at 3 m is highest.
South	Transect ends near the mouth of a seasonal creek off an undeveloped rocky shore (freshwater entering mainly in early spring).

Tab. 2: Summary of variables representing the changes in physical environment along the transect. For references with geographical locations refer to figure.2.
Tab. 2: Povzetek parametrov, ki ponazarjajo spremembe v fizičnem okolju vzdolž transketa. Glede podrobnosti o geografskih lokacijah na preučevanem območju glej sliko 2.

Physical environmental variable	Summary of results based on measurements
Benthic slope	Generally low, ranges from 0.8 to 1.8 %, lowest values in the north and highest in the southwest.
Sediment organic-matter content and water content	Organic-matter content ranged from 3.0 to 10.9%, water content ranged between 32 and 65%, with highest values in and near the marina and lowest values in the south and along the sand bank (southwest). Sediment organic-matter and water content were highly positively correlated ($p = 2.2x10^{-16}$, $R^2 = 0.94$).
Salinity	Ranged between 9 to 14 ppt in the winter and 32 and 34 ppt in the fall. In the fall salinity was significantly highest in the center of the transect, in winter salinity was significantly highest near the natural side (south).
Depth-dependent wave exposure index	Ranged between 6.90 and 6.99 and significantly increased with distance from the north and the south ends, but was slightly higher within the marina (6.95) than at the South end (6.90).

Seagrass responses to the physical environment

Mean shoot density of *Z. noltii* was 656 shoots/m^2 and significantly higher than that of *Z. marina* (111 shoots/m^2, $p = 5.9 \times 10^{-8}$). *Z. noltii* shoot density significantly increased with distance from marina ($p = 0.035$, $R^2 = 0.11$, Fig. 3) and was positively affected by bottom slope ($p = 0.45$, $R^2 = 0.093$; Tab. 3). Sediment characteristics, like organic and water content, had a marginally negative effect, while distance to a sandbank had a marginally positive effect (Tab. 3). On the contrary, *Z. marina* shoot density decreased with distance from marina ($p = 0.0003$, $R^2 = 0.34$; Fig. 3), was lowest near (alongside) the sand bank ($p = 0.0074$, $R^2 = 0.30$), and was negatively affected by benthic slope ($p = 0.033$, $R^2 = 0.11$; Tab. 4). *Z. marina* shoot density correlated positively with sediment organic content ($p = 0.0056$, $R^2 = 0.20$) and water content ($p = 0.0037$, $R^2 = 0.22$; Tab. 4).

The physical environment along the transect

The 3-m isobath transect reaches north to south from the town of Posedarje to the opposite natural shore (Fig. 2). Tables 1 and 2 summarize and describe changes of the overall environment and specific aspects of the physical environment along the transect.

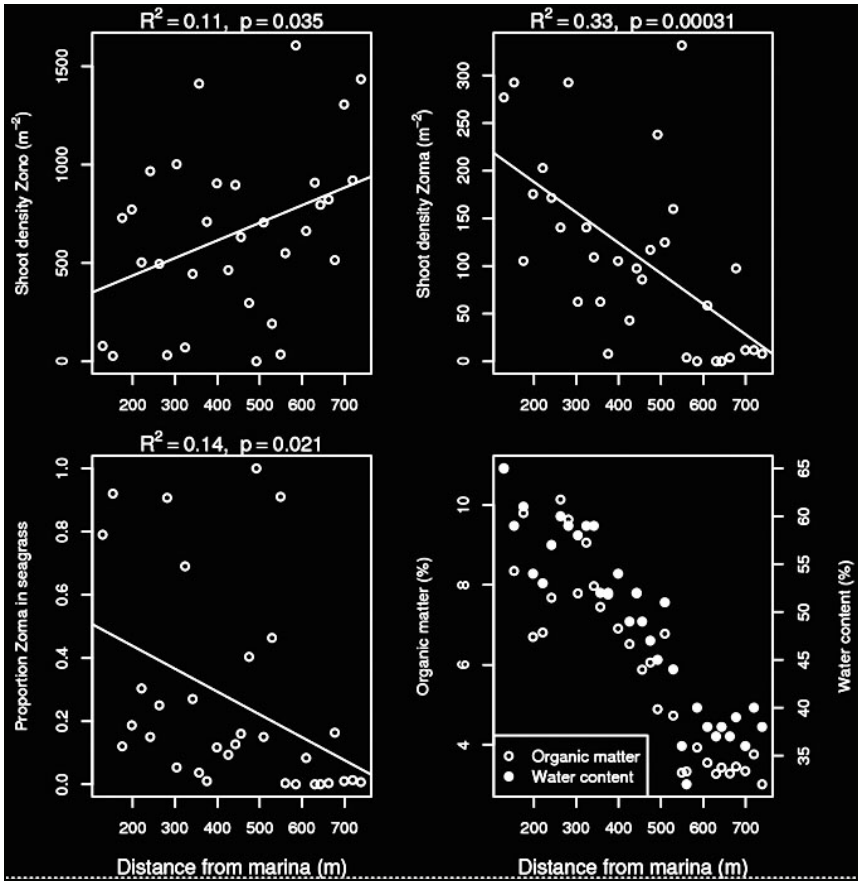

Fig. 3: Scatterplots, regression lines, and ANOVA results (distance from marina) for** Z. noltii **and** Z. marina **shoot densities, proportion of seagrass that was** Z. marina**, and sediment organic matter and water content.
Sl. 3: Razpršeni diagrami, regresije in rezultati ANOVE (razdalja od marine) za gostoto šopov vrst** Z. noltii **in** Z. marina**, delež morske trave, ki je bila** Z. marina**, organske usedline in vsebnost vode.

The proportion of seagrass showed that *Z. marina* was significantly correlated with the same predictor variables and in the same direction as *Z. marina* shoot density. Total shoot density showed less significant correlations with any of the predictor variables, but the directions of all responses were equal to those for *Z. noltii* shoot density. In a biplot (Fig. 4b), the first two principle components were the distance from the marina and the distance from the freshwater canal outlet (see in Fig. 2). Again, *Z. marina* shoot density is negatively correlated with the distance from marina and the freshwater canal, while *Z. noltii* is positively correlated with these two variables. In addition, *Z. marina* shows positive correlation with wave exposure and negative correlation with the slope, while the opposite is true for *Z. noltii*.

Tab. 3: ANOVA results for** Zostera noltii **shoot density; Df = 1.1. Statistically significant results are highlighted (bold).
Tab. 3: Rezultati analize variance (ANOVA) za gostoto šopov vrste** Zostera noltii**; Df = 1,1. Statistično značilni rezultati so poudarjeni (mastne črke).

Predictor variables	***Zostera noltii* shoot density**		
	F	**p**	**R^2**
distance from marina	4.86	**0.035**	0.11
distance from sand bank	3.1	0.088	0.064
distance from beach area	1.01	0.32	0.00037
distance from canal	3.32	0.078	0.060
wave exposure	3.72	0.063	0.080
salinity fall	0.11	0.74	-0.029
salinity winter	0.25	0.62	-0.025
bottom slope	4.18	**0.05**	0.093
sediment organic matter %	3.74	0.063	0.081
sediment water content %	3.03	0.092	0.061

Seagrass interactions

Z. marina shoot density was highly negatively and significantly correlated with *Z. noltii* shoot density ($p = 9 \times 10^{-11}$, $R^2 = 0.35$; Fig. 4a). When all physical variables were combined in a multiple regression analysis ($p = 0.0019$, $F = 3.14$, $Df = 10, 85$), only 18% of the variation in *Z. noltii* shoot density was explained and only fall salinity had an independent significant effect. A subsequent multiple regression analysis with *Z. marina* shoot density, added as one of the predictor variables ($p = 1.0 \times 10^{-7}$, $F = 6.51$, $Df = 11, 84$), significantly improved the model ($p = 5.14 \times 10^{-7}$, $F = 29.06$, $Df = 84, 85$ in comparison to the nested ANOVAs; Tab. 5) and explained additional 20.5% of the variation. The only physical variables having an independent significant effect on *Z. noltii* shoot density were fall salinity (positive), wave exposure (negative), sediment organic content (negative), and distance from a sand bank (negative).

Tab. 4: ANOVA results for** Zostera marina **shoot density; Df = 1.1. Statistically significant results are highlighted (bold).
Tab. 4: Rezultati ANOVE za gostoto šopov vrste** Zostera marina**; Df = 1,1. Statistično značilni rezultati so poudarjeni (mastne črke).

Predictor variables	*Zostera marina* shoot density		
	F	p	R^2
distance from marina	16.6	**0.00031**	0.33
distance from sand bank	14.12	**0.00074**	0.3
distance from beach area	8.4	**0.007**	0.19
distance from canal	1.29	0.26	0.0093
wave exposure	3.4	0.075	0.072
salinity fall	0.19	0.67	-0.027
salinity winter	2.51	0.12	0.047
bottom slope	5	**0.033**	0.11
sediment organic matter %	8.89	**0.0056**	0.2
sediment water content %	9.91	**0.0037**	0.22

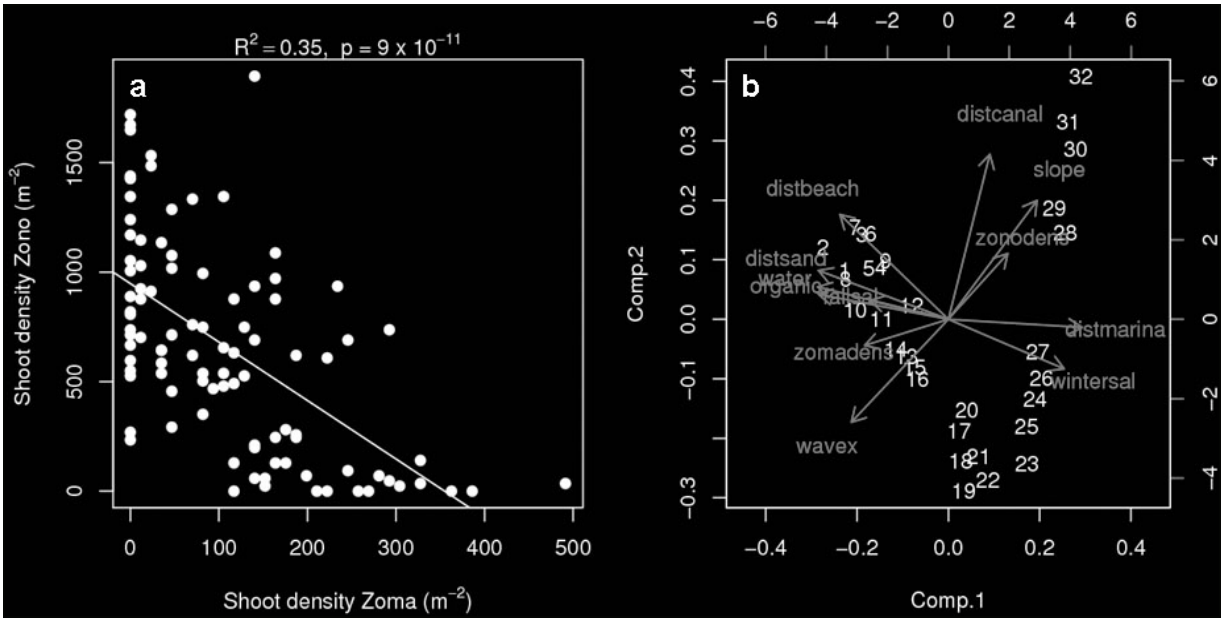

Fig. 4: (a) Scatterplot, regression line, and ANOVA results** (Z. marina **shoot density) for** Z. noltii **shoot density. (b) Standard biplot of the results of a principal components analysis (PCA) based on correlation among all variables. Legend: "dist" = distance, "sal" = salinity, "wavex" = wave exposure index, zoma =** Z. marina**, zono =** Z. noltii**, dens = shoot density, water = sediment water content, organic = sediment organic content.
Sl. 4: (a) Razpršeni diagram, regresija in rezultati ANOVE (gostota šopov vrste** Z. marina**) za gostoto šopov vrste** Z. noltii**. (b) Standard biplot-grafikon rezultatov analize glavnih komponent (PCA) sloni na korelaciji spremenljivk. Legenda: "dist" = razdalja, "sal" = slanost, "wavex" = indeks izpostavljenosti valovom, zoma =** Z. marina**, zono =** Z. noltii**, dens = gostota šopov, water = vsebnost vode v sedimentu, organic = vsebnost organske mase.

DISCUSSION

Both *Zostera* species were present and mostly co-occurred along the entire transect. There was no obvious spatial segregation, although *Z. noltii* was the species present over a larger linear distance than *Z. marina* and at a higher mean shoot density. The shoot densities of *Z. noltii* (range 0–1600 shoots/m^2) compare well with those found in mixed beds by Laugier *et al.* (1999) in a French Mediterranean lagoon (range 50–2,500 shoots/m^2), but were an order of magnitude lower than those found in a monospecific *Z. noltii* bed in a lagoon in southern Portugal (6,000–8,000 shoots/m^2; Cabaço *et. al.*, 2008). Similarly, *Z. marina* shoot density in the Novigrad Sea (range 0–333 shoots/m^2) was lower than described by Guidetti (2000) from monospecific *Z. marina* beds in the northwestern Adriatic (range 280–775 shoots/m^2), but compared well with shoot densities of *Z. marina* in mixed *Zostera* beds in a coastal lagoon in France (100–180 shoots/m^2; Laugier *et al.*, 1999).

Tab. 5: Results of a nested analyses of variance (Df = 11.84) of** Zostera noltii **shoot density with** Z. marina **shoot density included as one of the (otherwise physical environmental) predictor variables. Statistically significant results are highlighted (bold).
Tab. 5: Rezultati vgnezdene analize variance (Df = 11,84) gostote šopov vrste** Zostera noltii**, kjer je gostota šopov vrste** Z. marina **vključena kot ena izmed (sicer fizično okoljskih) prediktorskih parametrov. Statistično značilni rezultati so poudarjeni (mastne črke).

Predictor variables	*Z. noltii* shoot density		
	estimate	t	p
Z. marina shoot density	-2.54	-5.44	**5.14×10^{-7}**
distance from marina	11.88	1.38	0.17
distance from sand bank	31.14	1.68	0.096
distance from beach area	-29.84	-1.11	0.27
distance from canal	6.28	0.33	0.74
wave exposure	-13817.4	-1.68	0.096
salinity 1	-101.45	-2.34	**0.022**
salinity 2	-166.78	-1.54	0.13
bottom slope	-20029.9	-0.71	0.48
sediment organic matter %	-161.31	-2.15	**0.034**
sediment water content %	3465.96	1.54	0.13

In agreement with the two species' description worldwide, *Z. marina* was the larger species, with longer and broader leaves, and thus a larger mean leaf area (*Z. noltii* : 480 mm^2, *Z. marina*: 1385 mm^2, $p = 8.2 \times 10^{-14}$), also indicating a larger biomass per shoot. Individually, physical variables such as salinity, wave exposure, and bottom slope explained none or only very little of the variation in shoot density of *Z. marina* (0–11%, Tab. 4) and *Z. noltii* (0–8%, Tab. 3), while sediment characteristics did so to a larger extent (*Z. marina*: 20–22%, *Z. noltii*: 6–8%, Tabs. 3 and 4). *Z. marina* was positively affected by finer sediments with higher organic and water content, while the opposite was true for *Z. noltii*. Caniglia *et al.* (1992) showed a similar distribution of *Z. marina* and *Z. noltii* in the Venice lagoon based on grain size; *Z. noltii* occurred on coarse textured sediment (sand), while *Z. marina* inhabited finer substrate with higher organic content.

Z. marina reached highest shoot density, and highest relative abundance near the marina. This is consistent with the hypothesis that the marina environment increased the competitive ability of *Z. marina* within the mixed *Zostera* bed. The taller *Z. marina* may have been the better competitor in a low light environment associated with frequent sediment re-suspension (muddier sediment, more frequent disturbance), conditions that could have resulted in what we observed: both species grew tallest shoots within and near the marina (data not shown). In contrast to *Z. marina*, *Z. noltii* shoot density was highest outside the marina where *Z. marina* was absent or very sparse. The strong negative correlation of the two *Zostera* species' shoot densities could be evidence for competition; they explained a higher percentage of variation than any other predictor variable tested, and had an effect with far higher statistical significance than any of the other physical variables in the multiple regression (Tab. 5). We conclude that *Z. noltii* beds of the Novigrad Sea are likely to be successfully invaded by *Z. marina* in areas where sediments have a higher organic and water content and/or experience more mechanical disturbance (wave exposure and more frequent anthropogenic traffic). Here *Z. marina* may be better suited to tolerate mechanical stress by means of deeper and larger rhizomes that are more likely to remain after a severe disturbance *(e.g.* anchoring) allowing for quick re-growth of new shoots. The occurrences of small monospecific *Z. marina* patches may be the direct result of such disturbances. *Z. noltii* appears to be the better competitor on coarser and less disturbed sediments, where its high shoot density may prevent the establishment of *Z. marina* shoots. Among species with a seasonal growth pattern, the smaller species are known to show faster increase in shoot density than larger species (Marba *et al.*, 1996). Our findings corroborate the description of *Z. noltii* as the species tolerating high and low energy environments and a broad range of salinities in the Adriatic (den Hartog, 1970). Our results, however, somewhat contradict the finding that *Z. marina* requires protected areas (Guidetti, 2000). Most relatively wave protected areas in Adriatic bays are actually under an-

thropogenic use, and experience boat traffic and residential drainage carrying organic particles and sediment, which combined result in lowered light attenuation that could then be the more direct cause of *Z. marina* being able to invade or even replace *Z. noltii*. Future research should address the mechanisms allowing coexistence of the two species on the scale of centimetres across the wide range of physical conditions observed in this study.

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DOKAZI O TEKMOVALNOSTI MED MORSKIMI TRAVAMI V LAGUNI SREDNJEGA JADRANA (HRVAŠKA)

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POVZETEK

Avtorji članka so na izobatnem transektu v Novigrajskem morju (Hrvaška, srednji Jadran) našli dokaze o tekmovalnosti med sobivajočima morskima travama Zostera noltii *in* Z. marina. *Transekt je vključeval razvita (marina) in nerazvita območja obrežnega pasu. Pokritost s posameznima vrstama morske trave je bila ugotovljena s podvodno videografijo DGPS, medtem ko je bila gostota poganjkov ocenjena na osnovi primerkov, ki so jih nabrali potapljači. Izkazalo se je, da se vrsti na okolje odzivata povsem drugače: medtem ko sta se pokrovnost in gostota šopov vrste* Z. marina *zmanjševali z razdaljo od marine, sta se pokrovnost in gostota šopov vrste* Z noltii *povečevali. Prostorsko razširjenost vrst je bilo mogoče v precej večji meri pojasniti z vzajemnim delovanjem in vplivanjem dveh vrst kot pa z okoljski parametri. Sklep avtorjev je bil, da je tekmovalnost med dvema vrstama poglavitni proces, ki določa razširjenost obeh vrst iz rodu* Zostera *v Novigrajskem morju.*

Ključne besede: *Zostera*, tekmovalnost med morskimi travami, okoljski parametri, DGPS-videografija, Jadran

REFERENCES

Cabaço, S., R. Santos & C. M. Duarte (2008): The impact of sediment burial and erosion on seagrass: A review. Est. Coast. Shelf Sci., 79(3), 354–366.

Caniglia, G., S. Borella & B. Carpene (1992): Distribution of Sea-grasses *Zostera marina* L., *Zostera noltii* Hornem., *Cymodocea nodosa* Ucrea Asch. in Venice lagoon. Lav. Soc. Veneciana Sci. Nat., 17, 137–150.

Charpentier, A., P. Grillas, F. Lescuyer, E. Coulet & I. Auby (2005): Spatio-temporal dynamics of a *Zostera noltii* dominated community over a period of fluctuating salinity in a shallow lagoon, southern France. Est. Coast. Shelf Sci., 64, 307–315.

Dauwalter, D. C., W. L. Fisher & K. C. Belt (2006): Mapping Stream Habitats with a Global Positioning System: Accuracy, Precision, and Comparison with Traditional Methods. Environ. Manage., 37 (2), 271–280.

de Boer, W. F. (2007): Seagrass – sediment interactions, positive feedbacks and critical thresholds for occurrence: a review. Hydrobiologia, 591, 5–24.

den Hartog, C. (1970): The Seagrasses of the World. North-Holland, Amsterdam, 275 p.

Duarte, C. M. & J. Kalff (1988): Influence of lake morphology on the response of submerged macrophytes to sediment fertilization. Can. J. Fish. Aquat. Sci., 45, 216–221.

Fourqurean, J. W., G. V. N. Powell, W. J. Keworthy & C. Zieman (1995): The Effect of Long-Term Manipulations of Nutrient Supply on Competition between the Seagrasses *Thallassia testudium* and *Halodule wrightii* in Florida Bay. Oikos, 72(3), 349–358.

Google Earth 5.0 (2009) http://earth.google.com

Guidetti, P. (2000): Temporal dynamics of *Zostera marina* L. off the Lagoon of Grado (Northern Adriatic Sea, Italy). Bot. Mar., 43(6), 541–546.

Hootsmans, M. J. M., J. E. Vermaat & W. van Vierssen (1987): Seed-bank development, germination and early seedling survival of two seagrass species from the Netherlands: *Zostera marina* L. and *Zostera noltii* Hornem. Aquat. Bot., 28, 275–285.

Koch, E. W. (2001): Beyond light: physical, geological and geochemical parameters as possible submersed aquatic vegetation habitat requirements. Estuaries, 24, 1–17.

Krause-Jensen, D., M. F. Pedersen & K. Jensen (2003): Regulation of eelgrass *(Zostera marina)* cover along depth gradients in Danish coastal waters. Estuaries, 26, 866–877.

Laugier, T., V. Rigollet & M. L. de Casabianca (1999): Seasonal dynamics in mixed eelgrass beds, *Zostera marina* L. and *Z. noltii* Hornem., in a Mediterranean coastal lagoon (Thau lagoon, France). Aquat. Bot., 63, 51–69.

Lee, K., S. R. Park & Y. K. Kim (2007): Effects of irradiance, temperature, and nutrients on growth dynamics of seagrass: A review. J. Exp. Mar. Biol. Ecol., 350, 144–175.

Leoni, V., A. Vea, V. Pasquaini, C. Pergent-Martini & G. Pergent (2008): Effects of experimental reduction of light and nutrient enrichment (N and P) on seagrass: a review. Aquat. Conserv: Mar. Freshw. Ecosyst., 18, 202–220.

Marba, N., J. Cebrian, S. Enriquez & C. M. Duarte (1996): Growth patterns of Western Mediterranean seagrasses: species-specific responses to seasonal forcing. Mar. Ecol. Prog. Ser., 133, 203–215.

Norris, J. G., S. Wyllie-Echevierra, T. Mumford, A. Bailey & T. Turner (1997): Estimating basal area coverage of subtidal seagrass beds using underwater videography. Aquat. Bot., 58, 269–287.

Schultz, S. T. (2008): Seagrass monitoring by underwater videography: Disturbance regimes, sampling design, and statistical power. Aquat. Bot., 33, 228–238.

Schultz, S. T., C. Kruschel & T. Bakran-Petricioli (2009): Influence of seagrass meadows on predator-prey habitat segregation in an Adriatic lagoon. Mar. Ecol. Prog. Ser., 374, 85–99.

Sinovčić, G., M. Franičević & V. Čikeš Keč (2004): Unusual occurrence and some aspects of biology of juvenile gilt sardine *(Sardinella aurita* Velenciennes, 1847) in the Zrmanja River estuary (eastern Adriatic). Appl. Ichthyol., 20, 53–57.

Tanaka, Y. & H. Kayanne (2007): Relationship of species composition of tropical seagrass meadows to multiple physical environmental factors. Ecol. Res., 22, 87–96.

Touchette, B. W. (2007): Seagrass – salinity interactions: Physiological mechanisms used by submersed marina angiosperms for a life at sea. J. Exp. Mar. Biol. Ecol., 350, 194–215.

Touchette, B. W. & J. M. Burkholder (2000): Review of nitrogen and phosphorus metabolism in seagrasses. J. Exp. Mar. Biol. Ecol., 250, 133–167.

Vermaat, J. E., C. A. Verhagen & D. Lindenburg (2000): Contrasting responses in two population of *Zostera noltii* Hornem. to experimental photoperiod manipulation at two salinities. Aquat. Bot., 76, 179–189.

Widdows, J., N. D. Pope, M. D. Brinsley, H. Asmus & R. M. Asmus (2008): Direct effects of seagrass beds *(Zostera noltii* and *Z. marina)* on near-bed hydrodynamics and sediment resuspension. Mar. Ecol. Prog. Ser., 358, 125–136.

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SAPROBIOLOGICAL ANALYSIS OF LLAP WATER (KOSOVO)

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ABSTRACT

In spring 2004, we investigated diatom taxa (Bacillariophyta) at 4 sampling stations on the Llap River in Kosova. The saprobic index was calculated on the basis of microscopic analysis of diatom communities to evaluate water quality in the Llap. 52 species of diatom algae were determined. According to the presence of indicator species, Llap water could be classified into category II class (beta mesosaprobic level).

Key words: Llap River, diatoms, saprobity

ANALISI SAPROBIOLOGICA DEL FIUME LLAP (KOSOVO)

SINTESI

Nella primavera del 2004 gli autori hanno studiato i taxa di diatomee (Bacillariophyta) in 4 stazioni di campionamento sul fiume Llap in Kosovo. L'indice saprobico è stato calcolato in base all'analisi microscopica delle comunità di diatomee al fine di valutare la qualità dell'acqua del fiume Llap. Sono state determinate 52 specie di diatomee. In base alla presenza di specie indicatrici, l'acqua del fiume Llap può venire classificata come categoria di qualità II (livello beta mesosaprobico).

Parole chiave: fiume Llap, diatomee, saprobia

INTRODUCTION

Periphyton is the mixture of algae, bacteria and fungi that grows on rocks, snags, macrophytes and man-made structures in streams (Rutherford & Cuddy, 2005). Aquatic organisms can serve as indicators of the properties of the surrounding environment. They are applied mainly in the field of water quality and in its central part saprobity (Sladeckova & Sladecek, 1993). Saprobity describes the effects of the content of putrescible organic matter undergoing microbial decomposition. The common processes of eutrophication, pollution, degradation and selfpurification can be damaged or destroyed by toxic, radiochemical and some physical factors interfering with saprobity. Biological indicators enable us to distinguish individual saprobic levels by microscopical analysis (Sladeckova & Sladecek, 1993). Diatoms, a predominant component of the periphyton, have long been used as biological indicators for monitoring surface water quality (Whitton & Rott, 1996).

The aim of the study was to investigate the diatom community composition in the upstream of the river Llap to the town of Besiana (ex Podujeva), as well as to demonstrate the influence of pollution on the variation of diatom community. Composition of diatom communities was assessed by studying their density and taxonomic composition.

Periphyton diatom communities are important primary producers in rivers, streams and lakes, where their characteristics are influenced by several environmental factors.

MATERIAL AND METHODS

Study site

The Llap River is 79.4 km long, with its source located near the village of Bellasic. The Llap joins the Sitnica River in the central part of Kosovo. Temperature regime of the investigated river water depends upon meteorological conditions and season. Its maximum temperature of 21.7 ºC was reached during the summer, while its lowest temperature (2.4 ºC) was registered in January. The highest rainfall was recorded between October and March (data supplied by the Meteorological and Hydrological Service of Kosova), the lowest between June and August. The water level of the Llap varies from 40–86 cm.

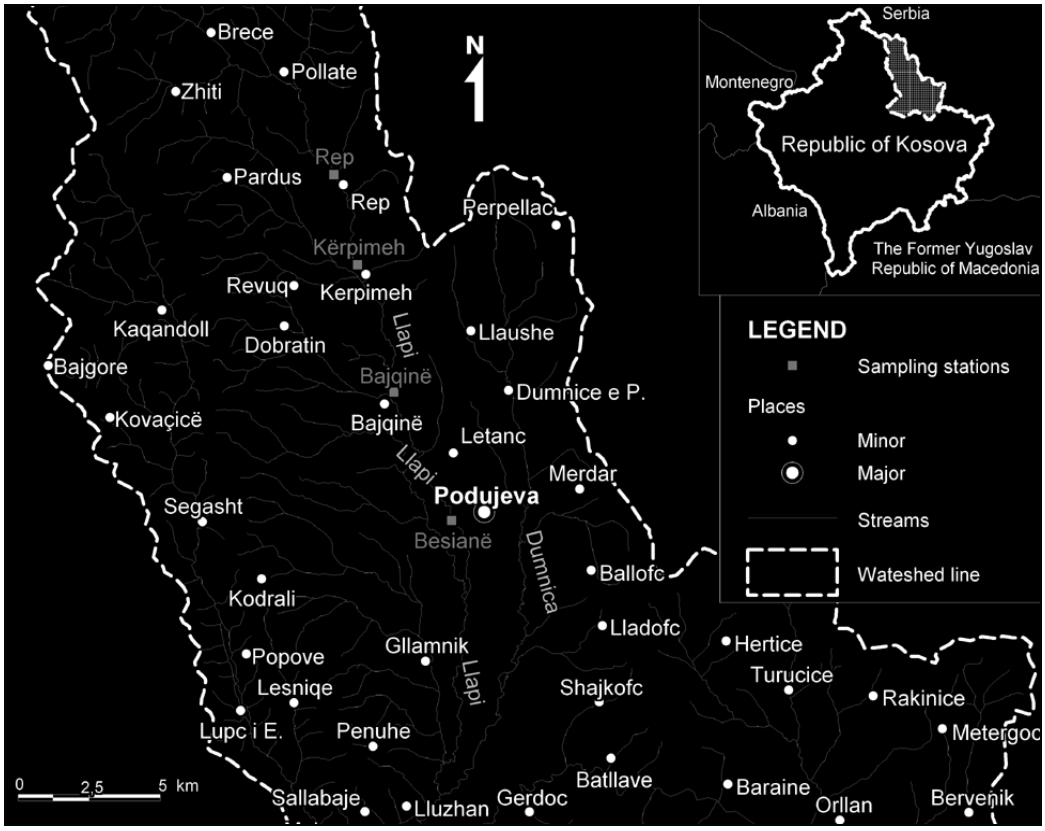

Fig.1: The map of the Llap River with sampling stations.
Sl. 1: Zemljevid reke Llap z vzorčišči.

Sampling localities:

1 – Right bank of the Llap River downstream of Repa village;

2 – Left bank of the Llap River in the centre of Kerpimeh village, after the inflow of the effluent waters from the sewage system;

3 – Right left bank of the Llap River near the bridge leading to Bajqinë village;

4 – Right bank of the Llap River after the inflow of waste waters from the Besiana town sewage system.

Material of phytobenthos was obtained by collecting sediments and stones taken from the river bottom (10–30 cm deepness) at four (4) stations between Repa and Besiana (Fig. 1).

The collected material was fixed with 4% formaldehyde and analysed in the laboratory of the Department of Biology, Faculty of Natural Science. Phytomicrobenthos was examined under "Leica" microscope. Determination of algae was described according to Geitler (1932), Gollerbah *et al.* (1953), Zabelina *et al.* (1951) and Lazar (1960). The levels of saprobity were estimated by Sladecek (1973), while the evaluation of saprobity was carried out on the basis of indicator species and standard procedure of Pantle & Buck (1955), Knopp (1954–1955) and Krammer & Lange Bertalot (1986–1991).

The relative abundance of the phytoplankton has been determined according to the modified sixth degree scale (Kawecka 1980).

Cleaning of diatoms and slide preparation

Cleaning of diatom frustules, preparation of permanent slides and determinations follow Krammer & Lange-Bertalot (1986–2001). The analysed water was put into a 600 ml glass beaker with 20 ml of concentrated HNO_3. The beaker was placed on a hotplate and heated until the volume of liquid was reduced to about 20 ml. From time to time, particles of $K_2Cr_2O_7$ were added. Eventually, the samples were rinsed with tap water until reaching 7 pH.

For slide preparation, a drop of water solution was put in the centre of a slide and left to dry. Than a drop of Hyrax mounting medium was added in the centre of coverslip and pressed gently with finger to spread the hyrax.

RESULTS AND DISCUSSION

The highest species number of diatoms was recorded at locality 1 (Repa), where 48 algal species were determined (Tab. 1). Localities 2 and 3 also had a relatively high number of species (31 taxa). In comparison with locality 1, the lower algal richness at localities 2 and 3 is probably due to the pollution caused by sewage waters falling into the Llap River at localities 2 (Kërpimeh village) and 3 (Bajqinë). At station 4, 21 diatom species were determined. The lower diatom richness could be ascribed to the pollution caused by sewage waters from the town of Besiana (former Podujeva), as well as to higher velocity of the river current at the other three stations (Medley & Clements, 1998; Fuertet - Mazel *et al.* 2003; Megharaj *et al.*, 2004; Zamaro, 2005). The development and seasonal variation of diatoms depend on various factors: velocity of the current, which influences their metabolism in terms of breathing, the pH of water, temperature (diatoms prefer fresh spring and autumn waters) and the oxygen present in the water (Zamaro, 2005). Density of algae depends on the substrate nature to which the diatoms adhere (Zamaro, 2005). Our study investigated whether algae-based water quality assessment is affected by differences between algal assemblages on hard substrates (rock, wood) and soft substrates (fine–grained sediments).

Tab. 1: Results of algological analyses of phytomicrobenthos in the upstream of the Llap River between Repa village and Besiana town in spring 2004.
Legend: o – oligosaprobic level; β – betamesosaprobic level; α – alphamesosaprobic level.
Tab. 1: Rezultati algoloških analiz fitomikrobentosa v toku reke Llap med vasjo Repa in mestom Besiana spomladi leta 2004.
Legenda: o – oligosaprobna stopnja; β – betamezosaprobna stopnja; α – alfamezosaprobna stopnja.

Taxa	Saprobic level	Locality			
		1	2	3	4
No. species per locality		48	31	31	21
Bacillariophyta					
Achnantes hungarica (Grunow)	o	1	1	-	-
Amphora lybica (Ehr)	β	-	1	-	1
A. normani (Rab)	o	2	-	1	-
Cocconeis placentula (Ehr)	β	1	1	-	-
C. pedicilus (Ehr)	o-β	1	-	-	-
Caloneis amphisbaena (Cl.)	β-α	1	-	-	-
Cymbela austriaca (Grun)	b	3	2	2	-

Taxa	Saprobic level	Locality			
		1	2	3	4
C. affinis (Kütz)	o-β	5	5	3	-
C. ventricosa (Kütz)	β	1	-	1	-
C. minuta (Hilse et Rab)		1	-	-	-
Craticula cuspidate (Kütz)Man		3	3	-	1
Cymatoplura solea (W.Smith)	β-α	-	3	1	-
Diatoma vulgare (Bory)	β	3	1	1	-
D. elongatum var. *tenuis*	α	1	-	1	-
D. monoliforme (Kütz)		1	1	-	-
Epthemia addnata (Kütz) Breb		1	-	-	-
Fragilaria ulna (Nitzsch) Lange-Bertalot		3	1	1	-
Gyrosigma acuminatum (Raben.)	β	-	-	-	1
G. scalproides (Cleve)		2	-	1	-
Gomphonema olivaceum (Kutz)	β	5	-	3	-
Hantzschia amphioxis (Grun)	α	1	-	-	-
Luticola geoppertiana (Bleish) Mann		3	3	2	-
Luticola mutica (Kütz)		3	1	-	1
Melosira varians (Ag)	β	1	3	-	3
Navicula gracilis (Ehr)	β-α	-	1	-	-
N. cryptocephala (Kütz)	α	3	1	5	1
N. exigua (Muller)	β	3		5	-
N. lanceolata (Agardh) Ehr.		1	1	-	1
N. radiosa (Kütz)	o-β	2	-	-	3
N. rhynchocephala (Kütz)	α	1	1	-	-
N. viridula (Kütz)	α	7	-	7	1
Nitzschia acicularis (W.Sm)	α	3	-	2	-
N. acula (Hantzch)	α	1	1	-	3
N. constricta (Kütz)		2	1	1	1
N. capitellata (Hust)		3	3	1	1
N. fonticola (Grun)	o-β	1	1	3	5
N. gracilis (Hatzsch)		-	3	1	-
N. hungarica (Grun)	α	5	-	3	5
N. palea (W.Sm)	α	1	-	2	-
N. paleacea (Grun)	-	3	1	2	-
N. recta (Hatzsch)	β-α	2	1	-	-
N. stagnorum (Raben)	β	1	1	-	3
N. sigmoidea (W.Sm)	β	-	-	1	1
N. termalis var. *minor* (Hisle)	-	1	-	-	2
N. vermicularis (Grun)	β	2	2	3	3
Pinnularia microstauron var. *brebissoni* (Kütz)	β	1	-	1	-
P. viridiformis (Nitzsch) Ehren		1	-	1	-
Roichosphaenia curvata (Gr)	β	2	1	1	-
Stauroneis anceps (Ehr.)	β	3	3	1	5
Synedra ulna (Her)	β	5	1	5	-
Surirella ovata (Kütz)	o-β	5	-	-	-
S. linearis (W.Smith)	β	1	1	3	1
S. robusta (Ehr.)		3	-	-	-
S. angusta (Ehr.)	β	1	1	3	5

Our results show that nearly in the entire part of the research area the algae of the genus *Nitzschia* with 14 species are prevalent. Other established taxa are the genus *Navicul*a with 7 species, *Surirella* and *Cymbella* with 4 species, *Diatoma* with 3 species, *Luticola, Gyrosigma, Pinularia, Cocconeis* and *Amphora* with 2 species, and other genus with 1 species. This species composition could be explained by the temperature of Llap water, which ranges in spring between 14–20 ºC, which is an optimum for the growing and development of the established groups of algae (Habdija, 1970; Grin, 1971; Oksijuk 1973; Maloseja, 1979; Hunter *et al.*, 2000). The abundance of diatoms also depends on light penetration (Hunter *et al.*, 2000; Zamaro, 2005).

Tab. 2: The saprobic index and saprobic level calculated for the Llap River according to the Pantle-Buck criteria (Pantle & Buck, 1955).
Tab. 2: Saprobni indeks in saprobna stopnja, izračunana za reko Llap glede na kriterije Pantle-Buck (Pantle & Buck, 1955).

Parameter	Localities			
	1	2	3	4
Saprobic index	1.67	1.62	1.72	1.71
Saprobic level	β	β	β	β
Quality class	II	II	II	II

Diatoms are ideal for biomonitoring purposes as they occur in very high numbers and are sensitive to changes in water chemistry (Fisher & Dunbar, 2007). They often have narrow tolerance range for pH, nutrients or salinity conditions (http://www.adelaide.edu.au/diatoma/stm.html).

Table 1 shows the list of 52 determined diatom species. For each of the 38 indicator species, saprobic level is denoted. We found 2 species characteristic of the oligosaprobic level, 5 oligo-beta-mesosaprob species, 18 beta-mesosaprobic species, 4 beta-alpha-mesosaprobic species and 9 species characteristic of the alpha-mesosaprobic level.

According to the bioindicator algal species determined in phytobenthos, the researched part of the Llap River belongs to quality class II (beta-mesopsaprobic level) (Tab. 2).

CONCLUSION

In the researched part of the Llap River, 52 species of diatoms were recorded. The highest number of taxa was found at locality 1 (Repa) with 48 species. 38 of them were bioindicator species. According to the presence of species as saprobiologic bioindicators and saprobic level, the researched part of the Llap River was classified into category II of the water quality.

SAPROBIOLOŠKA ANALIZA VODE REKE LLAP (KOSOVO)

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POVZETEK

Spomladi leta 2004 so avtorji članka preučevali taksone kremenastih alg (Bacillariophyta) na 4 vzorčiščih vzdolž reke Llap (Kosovo). Saprobni indeks je bil z namenom, da se oceni kakovost vode v reki, izračunan na osnovi mikroskopske analize združb kremenastih alg. Ugotovljenih je bilo 52 vrst kremenastih alg. Glede na pojavljanje bioindikatorskih vrst v reki Llap, lahko to reko vključimo v kakovostni razred II, kar pomeni, da pripada beta-mezosaprobni stopnji.

Ključne besede: reka Llap, kremenaste alge, saprobnost

REFERENCES

Fisher, J. & J. M. Dunbar (2007): Towards a representative periphytic diatom sample. Hydrol. Earth Syst. Sci., 11(1), 399–407. (www.hydrol-earth-syst-sci.net/11/399/2007)

Fuertet-Mazel, A., C. Gold, M. Coste & A. Boudua (2003): Study of periphytic diatoms communities exposed to metallic contamination through complementary field and laboratory experiments. 12th International Conference on Heavy Metals in the Environment, Grenoble, France, May 26–30, 2003. Journal de Physique, 107(1), 467–470.

Geitler, L. (1932): Cyanophyceae. In: Rabenhorst, L. (ed.): Kryptogamen – Flora. Akademische Verlagsgesellschaft, Leipzig, 1196 p.

Gollerbah, M. M., E. K. Kosinskaj & V. I. Poljanski (1953): Sinezelenie vodorosli. In: Gollerbah, M. M. & V. I. Poljanskii (eds.): Opredelitel Presnovodnih Vodoroslei SSSR. 2. Gosudarstvenoe Izdatelstvo "Sovetskaja nauka", Moskva, 651 str.

Grin, V. G. (1971): Donja algoflora vodemov–ohladitelei gres Ukraini. Gidrohimija gidrobiologijavodemov- ohladitelei elektrostanici SSSR. Izd. Nuakova dumka, Kiev, pp. 154–173.

Habdija, I. (1970): Odnos između stupnja saprobiteta i ekoloških faktora u gorskim potocima Veliki Markovac i Veliki Potok. Ekologija, 5(2), 159–178.

http://www.adelaide.edu.au/diatoma/stm.html: The University of Adelaide, 2006.

Kawecka, B. (1980): Sessile algae in European mountainstreams. 1. The ecological characteristics of communities. Acta Hydrobiol., 22(4), 361–420.

Knopp, H (1954–1955): Ein neuer Weg zur Darstellung biologischer Gewasserunter-suchungen, erlautert an einem Guelangsschnitt des Mains. Die Wasserwirtschaft, 45, 9–15.

Krammer, K. & H. Lange Bertalot (1986–1991): Bacillariophyceae. 1–4. Süsswasserflora von Mitteleuropa. Gustav Fischer Verlag, Stuttgart, New York.

Lazar, J. (1960): Alge Slovenije: seznam sladkovodnih vrst in ključ za določanje. Slovenska akademija znanosti in umetnosti, Ljubljana, 279 str.

Maloseja, Z. (1979): Laboratorijska ispitivanja utjecaja temperature Savske vode na razvoj nižih biljaka u perifitonu. II. kongres ekologa Jugoslavije. Zbornik referata, Zagreb, knjiga II., str. 261–268.

Matonickin, I., B. Stilinovic, I. Habdija, O. Biscan, R. Erben, Z. Maloseja & B. Primc (1982): Limnologijska istraživanja rijeke Rijecine. Poljoprivreda i sumarstvo, 28(2), 55–85.

Medley, C. N. & W. H. Clements (1998): Responses of diatom communities to the heavy metals in streams: the influence of longitudinal variation. Ecol. Appl., 8, 631–644.

Megharaj, M., L. H. Boul & H. J. Thiele (2004): Effect of DDT and its metabolites on soil algae and enzymatic activity. Biomed. Life Sci., 29(2), 130–134.

Oksijuk, O. P. (1973): Vodorsli kanalov mira. Naukova dumka, Kijev.

Pantle, R. & H. Buck (1955): Die biologische Uberwachung der Gewasser und die Darstellung der Ergenisse.Gas und Wassserfach, 96, 604 p.

Potapova, M. G. & D. F. Donald (2005): Choice of substrate in algae-based water-quality assessment. J. N. Am. Benthol. Soc., 24, 415–427.

Rutherford, J. C. & S. M. Cuddy (2005): Modelling periphyton biomass, photosynthesis and respiration in streams. CSIRO Land and Water Technical Report 23/05, Canberra, December 2005, 55 p.

Sladecek, V. (1973): System of water quality from the biological point of view. Arch. Hydrobiol. Ergenbnisse Limnol., 7, 1–218.

Sladeckova, A. & V. Sladecek (1993): Bioidication within the aquatic environment. Acta Universitatis Carolinae Environmentalica, 1, 3–69.

Whitton, B. A. & E. Rott (1996): Use of Algae for Monitoring Rivers. II. Institut fur Botanik, Innsbruck, 196 p.

Zabelina, M. M., I. A. Kieselev, A. I. Proskina Lavrenko & V. S. Sheshukova (1951): Inventory of Freshwater Algae of the USSR, Vol. 4. Diatoms. Sov. Nauka, Moscow, 619 p. *(in Russian)*

Zamaro, M. (2005): Water's Diatom CSI: a new methodological approach for the calculation, study and investigation of superficial waters quality. Industrial Technical Institute "Arturo Malignani", Udine, Italy.

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FITOCENOLOŠKA IN FLORISTIČNA ANALIZA OBREČNIH TRAVNIKOV PRI VASI SOČA (JULIJSKE ALPE) IN PREDLOGI ZA NJIHOVO VAROVANJE

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IZVLEČEK

Po standardni srednjeevropski fitocenološki metodi smo preučili travnike na rečnih nanosih pri vasi Soča v Julijskih Alpah. Uvrstili smo jih v tri asociacije: Ranunculo bulbosi-Arrhenatheretum elatioris, Centaureo dichroanthae-Globularietum cordifolii *in* Gentianello pilosae-Brometum erecti *ass. nov. hoc loco. V njihovem floristični nem inventarju sta tudi dva nova taksona za floro slovenskega dela Julijskih Alp (*Astragalus onobrychis *in* Plantago argentea *subsp.* liburnica) *in dve redki oz. ranljivi kukavičevki,* Herminium monorchis *in* Orchis coriophora *subsp.* coriophora. *Populacije steničje kukavice v Sloveniji in v srednji Evropi močno upadajo, pri vasi Soča (Za Otoki) pa je ta vrsta še razmeroma obilna in vitalna. Ohranja jo vsakoletna pozna košnja, h kateri spodbujamo upravljavca tega območja (Triglavski narodni park), da zanjo poskrbi tudi v prihodnje in jo razširi na vse preučene travnike.*

Ključne besede: fitocenologija, (pol)suha travišča, *Festuco-Brometea, Orchis coriophora*, Natura 2000, Julijske Alpe

ANALISI FITOCENOLOGICA E FLORISTICA DI PRATI FLUVIALI AL VILLAGGIO SOČA (ALPI GIULIE) E PROPOSTE PER LA LORO PROTEZIONE

SINTESI

Con l'ausilio del metodo fitocenologico standard centro-europeo sono stati studiati i prati fluviali in prossimità del villaggio Soča nelle Alpi Giulie. I prati appartengono a tre associazioni: Ranunculo bulbosi-Arrhenatheretum elatioris, Centaureo dichroanthae-Globularietum cordifolii *e* Gentianello pilosae-Brometum erecti *ass. nov. hoc loco. Nel loro inventario floristico si trovano anche due nuovi taxa per la flora della parte slovena delle Alpi Giulie (*Astragalus onobrychis *e* Plantago argentea *subsp.* liburnica) *e due orchidacee rare ossia vulnerabili, quali* Herminium monorchis *e* Orchis coriophora *subsp.* coriophora. *Le popolazioni dell'orchide cimicina in Slovenia e nell'Europa centrale sono in declino, mentre in prossimità del villaggio Soča (Za Otoki) la specie è ancora vitale e relativamente abbondante. A mantenerla tale è pure l'annuale tarda falciatura, effettuata del gestore dell'area (Parco Nazionale del Triglav), che verrà programmata anche in futuro e praticata in tutti i prati studiati.*

Parole chiave: fitocenologia, prati (semi)aridi, *Festuco-Brometea, Orchis coriophora*, Natura 2000, Alpi Giulie

UVOD

Travišča so ena izmed najbolj pisanih in pomembnih sestavin pokrajine v Julijskih Alpah. Še posebej to velja za njihov zavarovani del (Triglavski narodni park). V posoškem delu tega območja lahko v grobem ločimo tri glavne tipe travišč:

1. Naravna subalpinsko-alpinska travišča so razširjena v visokogorju, nad zgornjo gozdno mejo (Surina, 2005). Na njihovo vrstno sestavo in zunanjo podobo vplivajo predvsem naravni procesi (npr. divjad, plazovi ipd.), manj pa človek (potencialno npr. z graditvijo smučišč, planinskih koč). Svojčas so bili to visokogorski pašniki, deloma so ta travišča celo kosili oz. želi. Sledove nekdanje rabe ponekod še opazimo v floristični sestavi (npr. na travnikih, kje so nekoč pasli konje). Geološko podlago navadno sestavljata apnenec in dolomit, tla so plitva (rendzina, litosol).
2. Drugotna gorska travišča ob in pod sedanjo zgornjo gozdno mejo na mešani geološki podlagi (apnenec s primesjo laporovca, glinavca in roženca) in na nekoliko globljih tleh. V to skupino uvrščamo npr. vrstno bogate in v glavnem opuščene senožeti pod grebenom Tolminsko-Bohinjskih gora nad Baško dolino (Dakskobler, 2003a; Dakskobler *et al.*, 2005, 2007), nekdanje senožeti na prisojnih pobočjih Stolovega grebena nad Breginjskim kotom (Čušin, 2006), podobne senožeti v Planji nad dolino Učje ter senožeti pod Krnovim grebenom nad Drežnico in sosednjimi vasmi (Dakskobler, 2001). Na njih poznamo nahajališča redkih, zavarovanih in/ali varstveno pomembnih rastlin, kot so *Eryngium alpinum*, *Asphodelus albus*, *Paradisea liliastrum, Gladiolus palustris* idr. Sestava teh travnikov je precej bolj izpostavljena spremembam. Pogoj za njihovo ohranitev je vsakoletna košnja. Ko z njo prenehamo, se začne proces sekundarne sukcesije (ponovno vračanje gozda na površine, kjer je nekoč že uspeval), ki pa je precej dolgotrajen. Na teh senožetih se najprej povečata množina in zastiranje visokih steblik in vrst gozdnih robov (npr. kobulnic, kot sta *Laserpitium siler* in *Laserpitium latifolium),* za njimi se postopno naselijo tudi grmovne in drevesne vrste. Zaraščanje z gozdom na strmih prisojnih senožetih precej zavirajo vsakoletni snežni plazovi.
3. Drugotna dolinska travišča na rečno-ledeniških (fluvio-glacialnih) nanosih na plitvih rendzinah (npr. v zatrepu doline Tolminke, v dolinah Loške Koritnice, Lepene, Bavšice, Zadnjice in Zadnje Trente). Deloma so to še aktivni pašniki, ponekod te travnike kosijo. Veliko jih je opuščenih in jih navadno zaraščajo pionirski smrekovi sestoji. Človek njihovo rabo spreminja npr. z graditvijo stanovanjskih in turističnih objektov (kampi). Večinoma so ti travniki zelo ogroženi, njihova vrstna pestrost je odvisna od rabe (paša, košnja, vnos hranil), v splošnem pa je (še) velika. Dno alpskih dolin v Posočju je le nekaj sto metrov nad morsko gladino (400 do 800 m nm. v.), te doline so v glavnem odprte proti jugu (vpliv submediterana), zato na teh travnikih ponekod opažamo, kako skupaj uspevajo alpske, srednjeevropske in submediteranske (toploljubne) rastline, kar je posebnost tega dela Julijskih Alp. O tem smo, na primeru doline Lepene in travnikov pri vasi Soča, pisali pred nekaj leti (Dakskobler *et al.*, 2007), ko smo predstavili nekatere tamkajšnje floristične posebnosti (nova nahajališča vrst *Cytisus pseudoprocumbens*, *Plantago holosteum* in *Carex praecox* subsp. *praecox).* Leta 2008 smo na teh travnikih našli še nekatere druge redke ali varstveno pomembne vrste *(Astragalus onobrychis, Herminium monorchis* in *Orchis coriophora* – o slednji je pisal Završnik, 2008), to pa nas je spodbudilo, da te travnike podrobneje fitocenološko in floristično preučimo ter predlagamo, kako bi jih bilo treba zavarovati.

METODE

Raziskavo smo omejili na obrečna travišča na levem bregu Lepenice, tik pred sotočjem s Sočo – nasproti kampa Klin (Trebež) in na podobne travnike na levem bregu Soče po toku navzdol (Za Otoki). En popis smo naredili tudi na desnem bregu Soče pod zaselkom Podklanec (Sl. 1).

Ti travniki so del Triglavskega narodnega parka (kvadrant 9647/4 po srednjeevropskem kartiranju flore). Geološka podlaga so rečni nanosi (aluvij) – Buser (1986, 1987) ter Jurkovšek (1987a, b), tla pa so ponekod še hidromorfna, obrečna (fluvisol), v glavnem pa že avtomorfna (rendzina).

Soča in spodnji del Lepene imata humidno gorsko podnebje, s povprečno letno množino padavin okoli 2300 mm (povprečje v razdobju 1961–1990 za merilno postajo Soča, 487 m nm. v., je bilo 2353 mm; Zupančič, 1995) in povprečno letno temperaturo okoli 9 °C. Temperaturne podatke imamo le za nekoliko južneje ležeči Bovec (452 m nm. v.), kjer so v razdobju 1961–1990 izmerili povprečno letno temperaturo 9,2 °C (interpolirana vrednost), najhladnejši mesec je bil januar (–0,7 °C), najtoplejši pa julij (18,7 °C) (Mekinda-Majaron, 1995). Preučeni travniki so ponekod v stiku z obrečnimi logi sive vrbe, velikega jesena in smreke, ki jih uvrščamo v asociacijo *Lamio orvalae-Salicetum eleagni* (Dakskobler, 2007), potencialno naravna gozdna vegetacija v okolici pa je predvsem alpski bukov gozd *(Anemono trifoliae-Fagetum).*

Sl. 1: Nahajališča popisanih travnikov pri vasi Soča. (Vir: Državna topografska karta RS 1 : 25000, GURS).
Fig. 1: Localities of recorded meadows near the village of Soča. (Source: State topographical map 1 : 25000, GURS).

Travišča v vasi Soča smo popisali po srednjeevropski fitocenološki metodi (Braun-Blanquet, 1964). Fitocenološke popise smo vnesli v bazo podatkov FloVegSi (Seliškar *et al.,* 2003) in to aplikacijo uporabili tudi pri pripravi zemljevidov in arealnih kart. Popise smo v tabelo 1 uredili z numeričnimi metodami (hierarhično klasifikacijo, PCoA-ordinacijo). Uporabljali smo programski paket SYN-TAX (Podani, 2001). Isti programski paket in iste metode smo uporabili tudi pri primerjavi (pol)suhih submontansko-montanskih travišč Furlanije, Slovenije in Hrvaške, v katerih prevladuje vrsta *Bromus erectus* s. lat.

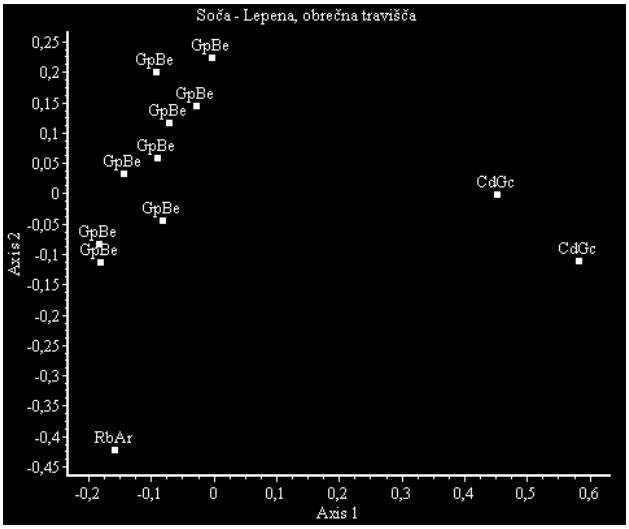
Nomenklaturni vir za imena praprotnic in semenk je Mala flora Slovenije (Martinčič *et al.,* 2007), razen pri vrstah *Bromus erectus* Huds. in *Sanguisorba minor* Scop. subsp. *muricata* (Spach) Asch. & Graebn. Nomenklaturna vira za imena mahov sta Frahm & Frey (1992) in Martinčič (2003). Vrste smo po fitocenološki pripadnosti (glede na njihovo navezanost na določene združbe iz sintaksonomskega sistema) razvrščali po lastnih merilih ob upoštevanju številnih avtorjev. Predvsem smo si pomagali z delom Flora alpina (Aeschimann *et al.,* 2004), ki je tudi vir za horološko (geoelementno) oznako popisanih vrst. V članku omenjene sintaksonomske enote z njihovimi avtorji navajamo v dodatku.

Pri opisu lokacij smo uporabljali temeljne topografske karte RS 1 : 10000 (GURS), Atlas Slovenije v merilu 1 : 50000 (3. izdaja, 1996) in turistično karto občine Bovec 1: 40000 (LTO Bovec, 2004). Vira za varstveni statusu popisanih rastlin sta UL RS 82/2002 in Skoberne (2007).

REZULTATI IN RAZPRAVA

Fitocenološka analiza obrečnih travišč pri vasi Soča

V Tabeli 1 smo napravili 12 fitocenoloških popisov (njihova nahajališča so na sliki 1). Popisi se po primerjavi z numeričnimi metodami združujejo v tri skupine (Sl. 2).



Sl. 2: Dvorazsežni ordinacijski diagram popisov v tabeli 1 (PCoA, similarity ratio). Legenda: RbAr *(Ranunculo bulbosi-Arrhenatheretum),* ***GpBe*** *(Gentianello pilosae-Brometum erecti),* ***CdGc*** *(Centaureo dichroanthae-Globularietum cordifoliae).*

Fig. 2: Two-dimensional scatter-diagram of relevés in Table 1 (PCoA, similarity ratio). Legend: RbAr *(Ranunculo bulbosi-Arrhenatheretum),* ***GpBe*** *(Gentianello pilosae-Brometum erecti),* ***CdGc*** *(Centaureo dichroanthae-Globularietum cordifoliae).*

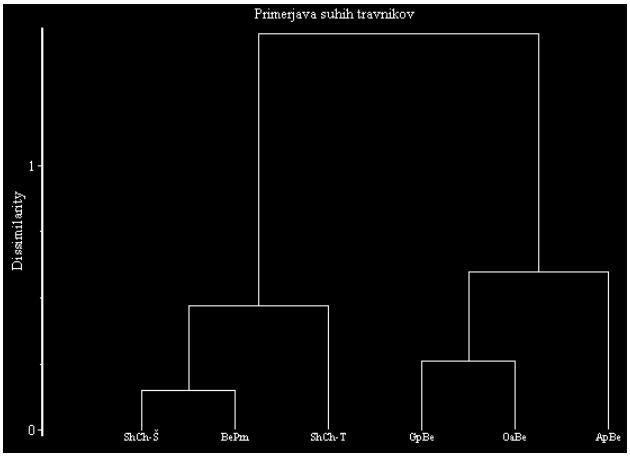
V prvi je le en popis (št. 1), v katerem prevladujejo vrste gojenih travnikov iz razreda *Molinio-Arrhenetheretea*, tako da ta sestoj začasno uvrščamo v asociacijo *Ranunculo bulbosi-Arrhenetheretum elatioris*. V njem obilno uspeva vrsta *Carex praecox*. Večina popisov sodi v drugo skupino, v kateri prevladujejo vrste suhih in polsuhih topoljubnih srednje- in južnoevropskih travišč iz razreda *Festuco-Brometea*. Njihova posebnost je, da v njih uspevajo tudi nekatere submediteranske oz. ilirsko-submediteranske vrste (npr. *Plantago holosteum* in *P. argentea* subsp. *liburnica),* prav tako nekatere vrste, značilne za subalpinsko-alpinska travišča iz razreda *Elyno-Seslerietea* (npr. *Thymus praecox* subsp. *polytrichus, Helianthemum nummularium* subsp. *grandiflorum*, *Ranunculus carinthiacus*, *Globularia cordifolia*, *Betonica alopecuros* in *Galium anisophyllon*). Za njihovo ustrezno sinsistematsko oznako smo izdelali sintezno tabelo (Tab. 2), v katero smo poleg preučene združbe (oznaka GpBe, popisi 2–10 v Tabeli 1) uvrstili še naslednje sintaksone:

– OaBe *Onobrychido arenariae-Brometum erecti* Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993 (Feoli Chiapella & Poldini, 1993, tabela 6, 46 popisov);
– ApBe *Avenulo praeustae-Brometum erecti* Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993 (Feoli Chiapella & Poldini, 1993, tabela 8, 8 popisov);
– ShCh-Š *Scabioso hladnikianae-Caricetum humilis* (Horvat 1931) Tomažič 1941 (Škornik, 2003, tabela 1, stolpec 1, 39 popisov);
– ShCh-T *Scabioso hladnikianae-Caricetum humilis* (Horvat 1931) Tomažič 1941 (Tomažič, 1941, 79, 12 popisov);
– BePm *Bromo-Plantaginetum mediae* Horvat (1931) 1949 (Šugar, 1972, tabela 20, popisi 1–22).

Primerjava z numerično klasifikacijo (Sl. 3) kaže, da so naši sestoji nekoliko bolj podobni montanskim suhim traviščem v Furlaniji kot združbam iz Slovenije in Hrvaške. Njihovo samosvojost bolje pokaže dvorazsežni ordinacijski diagram (Sl. 4). Na podlagi sintezne tabele in numeričnih primerjav preučenih travnikov ni mogoče uvrstiti v suha submontansko-montanska travišča iz asociacije *Scabioso hladnikianae-Caricetum humilis* (inc. *Bromo-Plantaginetum mediae* in *Bromo-Brachypodietum pinnati*) (Škornik, 2003), prav tako ne v asociacijo *Onobrychido arenariae-Brometum erecti* (katere sestoji so geografsko blizu in floristično še najbolj podobni, prim. Sl. 3) in tudi ne v asociacijo *Avenulo preustae-Brometum erecti* (Feoli Chiapella & Poldini, 1993).

Popise 2–10 v Tabeli 1 zato uvrščamo v novo asociacijo *Gentianello pilosae-Brometum erecti* ass. nov. hoc loco. Njene razlikovalnice so taksoni *Gentianella pilosa*, *Primula veris* subsp. *columnae*, *Plantago holosteum, Ranunculus carinthiacus, Orchis coriophora* subsp. *coriophora* in *O. militaris*. Naštete vrste novo asociacijo dobro razlikujejo od podobnih primerjanih združb (glej Tabelo 2). Njihovo skupno uspevanje kaže na dealpinsko (pol)suho obrečno travišče v alpski dolini z opaznim submediteranskim vplivom. *Gentianella pilosa* (= *Gentiana pilosa)* je vzhodnoalpska vrsta, značilnica suhih travišč iz zveze *Mesobromion*, in novo asociacijo označuje tudi horološko. Nomenklaturni tip (*holotypus*) nove asociacije je popis št. 3 v Tabeli 1. Če sledimo sinsistematski shemi suhih travišč v Furlaniji (*ibid.*), lahko novo asociacijo uvrstimo v ilirsko-predalpsko podzvezo *Hypochoeridion maculatae* (Horvatić 1973) Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993, v zvezo *Scorzonerion villosae* Horvatić 1949 in v red *Scorzonero-Chrysopogonetalia*. Med značilnicami tega reda na preučenih travnikih uspevajo taksoni *Sanguisorba minor* subsp. *muricata, Plantago holosteum*, *Plantago argentea* subsp. *liburnica* in *Centaurea scabiosa* subsp. *fritschii*. V prid taki uvrstitvi, ki ji začasno dajemo prednost, sta tudi dendrogram na sliki 3 in Tabela 2. Mogoča pa je tudi uvrstitev v zvezo *Mesobromion* in v red *Brometalia erecti*, kar bi bolj ustrezalo shemi, ki je v veljavi v Sloveniji (Kaligarič, 1997; Kaligarič & Škornik, 2002; Škornik & Kaligarič, 2002; Škornik, 2003). Dokončna sinsistematska uvrstitev nove asociacije v višje enote je torej še predmet nadaljnjih raziskav.

V tretji skupini v Tabeli 1 sta dva popisa, v katerih so vrstam (pol)suhih travišč razreda *Festuco-Brometea* po obilnosti skoraj enakovredne vrste subalpinskih travišč iz



Sl. 3: Dendrogram (pol)suhih submontansko-montanskih travnikov Furlanije, Slovenije in Hrvaške (MISSQ, similarity ratio). Legenda: GpBe *(Gentianello pilosae-Brometum erecti),* ***OaBe*** *(Onobrychido arenariae–Brometum erecti),* ***ApBe*** *(Avenulo praeustae-Brometum erecti),* ***ShCh-Š*** *(Scabioso hladnikianae-Caricetum humilis,* ***popisi S. Škornik), ShCh-T*** *(Scabioso hladnikianae-Caricetum humilis,* ***popisi G. Tomažič), BePm*** *(Bromo-Plantaginetum mediae).*

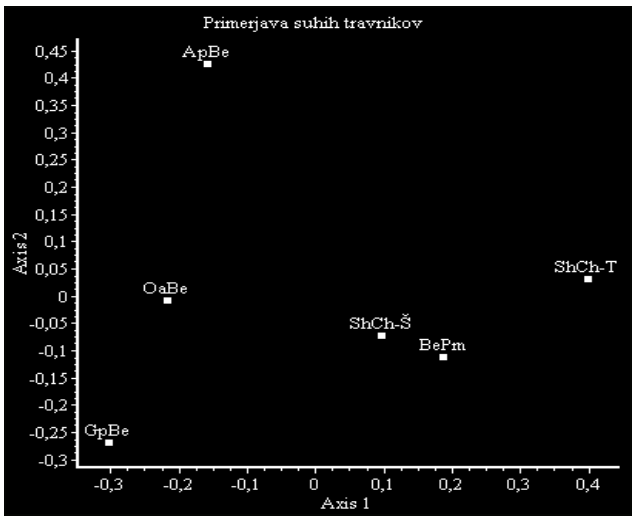
Fig. 3: Dendrogram of (semi)dry submontane-montane meadows in Friuli, Slovenia and Croatia (MISSQ, similarity ratio). Legend: GpBe *(Gentianello pilosae-Brometum erecti),* ***OaBe*** *(Onobrychido arenariae–Brometum erecti),* ***ApBe*** *(Avenulo praeustae-Brometum erecti),* ***ShCh-Š*** *(Scabioso hladnikianae-Caricetum humilis,* ***relevés of S. Škornik), ShCh-T*** *(Scabioso hladnikianae-Caricetum humilis,* ***relevés of G. Tomažič), BePm*** *(Bromo-Plantaginetum mediae).*

razreda *Elyno-Seslerietea*. Po celotni floristični sestavi sta ta dva sestoja še najbolj podobna sestojem asociacije *Centaureo dichroanthae-Globularietum cordifoliae*, čeprav v njiju nismo popisali njenih značilnic (prim. Feoli Chiapella & Poldini, 1993, tabela 1). To je zelo inicialna združba južnoalpskega prigorja, na plitvih, kamnitih tleh, v kateri uspeva tudi precej meliščnih vrst iz razreda *Thlaspietea rotundifolii*. Sinsistematsko torej preučena obrečna travišča označimo takole:

Molinio-Arrhenatheretea R. Tüxen 1937 em. R. Tüxen 1970
Arrhenatheretalia R. Tüxen 1931
Arrhenatherion elatioris Koch 1926
Ranunculo bulbosi-Arrhenatheretum **Ellmauer in Ellmauer & Mucina 1993**
Festuco-Brometea Br.-Bl. & Tüxen 1943
S*corzonero-Chrysopogonetalia* Horvatić & Horvat in Horvatić 1958 = *Scorzoneretalia villosae* Horvatić 1975
Scorzonerion villosae Horvatić 1949
Hypochoeridion maculatae (Horvatić 1973) Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993
Gentianello pilosae-Brometum erecti ass. nov. hoc loco
Satureion subspicatae Horvat 1962
Centaurenion dichroanthae (Pignattti 1953) Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993
Centaureo dichroanthae-Globularietum cordifoliae **Pignatti 1953**

Po habitatni tipologiji (Jogan *et al.*, 2004) preučene travnike uvrščamo v naslednje habitatne tipe:

– srednjeevropski kseromezofilni travniki na razmeroma suhih tleh s prevladujočo visoko pahovko (tja sodi popis 1 v Tabeli 1, ki ga uvrščamo v asociacijo *Ranunculo bulbosi-Arrhenatheretum*);
– srednjeevropska zmerno suha travišča s prevladujočo pokončno stoklaso (popisi 2–10 v Tabeli 1, uvrščamo jih v asociacijo *Gentianello-Brometum erecti*);
– srednjeevropska dealpinska suha travišča z vilovinami (v ta habitatni tip sodita popisa 11 in 12 v Tabeli 1, uvrščamo ju v asociacijo *Centaureo dichroanthae-Globularietum cordifoliae*).



Sl. 4: Dvorazsežni ordinacijski diagram (pol)suhih submontansko-montanskih travnikov Furlanije, Slovenije in Hrvaške (PCoA, similarity ratio). Legenda: GpBe *(Gentianello pilosae-Brometum erecti),* ***OaBe*** *(Onobrychido arenariae–Brometum erecti),* ***ApBe*** *(Avenulo praeustae-Brometum erecti),* ***ShCh-Š*** *(Scabioso hladnikianae-Caricetum humilis,* ***popisi S. Škornik), ShCh-T*** *(Scabioso hladnikianae-Caricetum humilis,* ***popisi G. Tomažič), BePm*** *(Bromo-Plantaginetum mediae).*

Fig. 4: Two-dimensional scatter-diagram of of (semi)dry submontane-montane meadows in Friuli, Slovenia and Croatia (PCoA, similarity ratio). Legend: GpBe *(Gentianello pilosae-Brometum erecti),* ***OaBe*** *(Onobrychido arenariae–Brometum erecti),* ***ApBe*** *(Avenulo praeustae-Brometum erecti),* ***ShCh-Š*** *(Scabioso hladnikianae-Caricetum humilis,* ***relevés of S. Škornik), ShCh-T*** *(Scabioso hladnikianae-Caricetum humilis,* ***relevés of G. Tomažič), BePm*** *(Bromo-Plantaginetum mediae).*

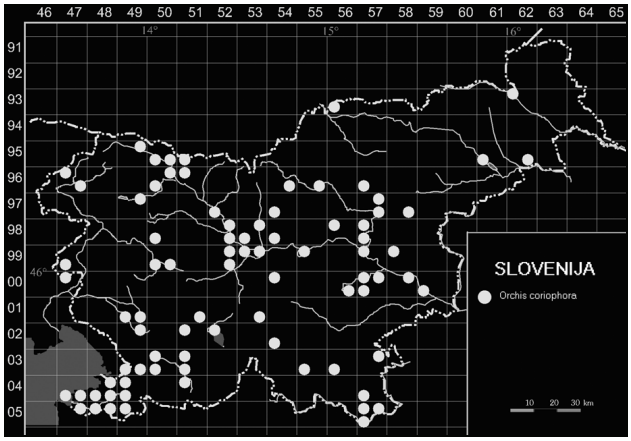
Floristična analiza preučenih travišč, s poudarkom na redkih in zavarovanih vrstah

Na preučenih travnikih pri vasi Soča smo doslej popisali 169 semenk, 2 praprotnici *(Ophioglosssum vulgatum in Selaginella helvetica)* ter 5 mahov (slednje smo preučili zelo nepopolno). Vrstna sestava teh travnikov je bogata, saj smo na njih ugotovili povprečno 57 vrst na popis (standardni odklon je 9,1, koeficient variacije pa 15,9%).

Na teh travnikih rastejo naslednje zavarovane vrste slovenske flore (Skoberne, 2007): *Dianthus sternbergii*, *Arctostaphylos uva-ursi, Gentiana clusii, Orchis coriophora, O. ustulata, O. militaris, Gymnadenia conopsea, G. odoratissima, Herminium monorchis* in *Listera ovata* ter naslednje vrste z našega Rdečega seznama (UL RS 82/2002): ranljive vrste (V): *Carex distans, Gymnadenia conopsea, G. odoratissima, Herminium monorchis, Leontodon berinii, Ophioglossum vulgatum, Orchis coriophora, O. ustulata, O. militaris*; vrste zunaj nevarnosti (zavarovane, a neogrožene) O1: *Dianthus sternbergii, Gentiana clusii*.

Med naštetimi vrstami je precej takih, ki so v tem območju (Zgornje Posočje) in tudi drugod v Sloveniji še razmeroma pogoste ali pa neogrožene (take so npr. *Dianthus sternbergii, Arctostaphylos uva-ursi, Gentiana clusii, Gymnadenia conopsea, G. odoratissima, Orchis militaris, Listera ovata*). Podobno ugotavljamo za kačji jezik *(Ophioglossum vulgatum)*. V zadnjih letih smo med Bovcem in Trento našli kar nekaj njegovih nahajališč, npr. v Zadnji Trenti, v Vrsniku in v dolini Lepene (Dakskobler *et al.,* v pripravi) in tudi sicer je ta vrsta v Sloveniji razmeroma pogosta. V neposredni bližini preučenih travnikov, v sestojih sive vrbe in velikega jesena pri Koči tolminskih tabornikov, raste še ena ranljiva praprotnica, *Botrychium virginianum* (Dakskobler, 2003b).

Med popisanimi kukavicami je vrsta *Orchis ustulata* v Sloveniji razmeroma ogrožena in v upadanju (Jogan, 2007a). Še bolj ta ugotovitev velja za takson *Orchis coriophora* subsp. *coriophora*. Po objavljenih arealnih kartah (Jogan *et al.*, 2001; Ravnik, 2002; njune podatke in podatke, zbrane v bazi FloVegSi Biološkega inštituta ZRC SAZU, povzemamo v sliki 5) je sicer v Sloveniji razmeroma veliko znanih nahajališč, vendar jih je mnogo starejšega datuma (in brez novejših potrditev), zato ocenjujejo, da je ta takson izrazito v upadanju (Jogan, 2007a). Podobno velja tudi drugod v srednji Evropi (Presser, 2000; Perko, 2004). Jogan *et al.* (2001) za Zgornje Posočje navajajo podatek za kvadrant 9647/1 (v dolini Možnice ga je pred več kot 40 leti opazil Wraber (1967)), vendar nam vir za ta podatek ni znan. Na preučenih travnikih Za Otoki smo junija 2008 popisali vsaj 100 primerkov steničje kukavice, kar tem travnikom daje, zaradi njene splošne ogroženosti, velik varstveni pomen.

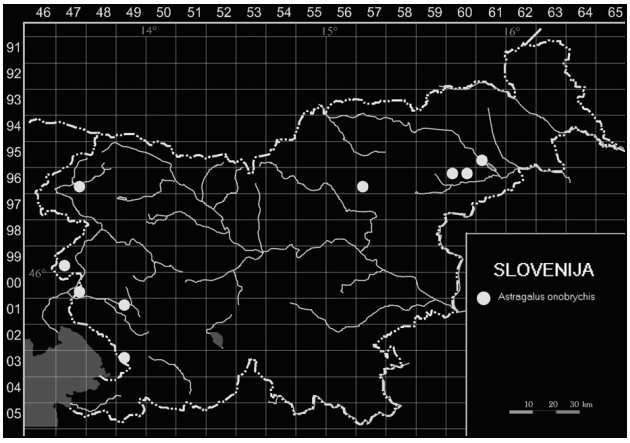


Sl. 5: Razširjenost vrste** Orchis coriophora **v Sloveniji.
Fig. 5: Distribution of** Orchis coriophora **in Slovenia.

Redka in ranljiva, tako v Zgornjem Posočju kot na splošno v Sloveniji, je vrsta *Herminium monorchis*. Na Bovškem so znana nahajališča še v Zadnji Trenti (Dolinar, 2001) in v okolici Bovca (Wraber, 1967).

Med drugimi zavarovanimi oz. ranljivimi vrstami naj omenimo še vrsto *Leontodon berinii*, ki je endemična v jugovzhodnih Alpah in skoraj vedno raste le na rečnem, potočnem ali hudourniškem produ (Wraber, 1990). En šop smo popisali na suhem inicialnem travišču na poraslem produ pod zaselkom Podklanec (popis 12 v Tabeli 1), en šop pa našli v pionirskem vrbovju *(Salicetum incano-purpureae)* na prodnatem otočku Soče pod bunkerji Za Otoki.

Posebnost travišč pri vasi Soča sta tudi dva trpotca, *Plantago holosteum* in *P. argentea* subsp. *liburnica*. Vrsta *Plantago holosteum* ima v slovenskem delu Julijskih Alp doslej znana nahajališča v dolini Lepene, pri vasi Soča in na pl. Osojnica v dolini Tolminke. Ilirsko razširjeno (Ravnik, 1988) podvrsto južnoevropsko-montanskega srebrnega trpotca *(Plantago argentea* subsp. *liburnica)* pa v slovenskem delu Julijskih Alp doslej po nam znanih podatkih sploh niso poznali (Jogan *et al.*, 2001; Jogan, 2007b), ima pa ta takson več nahajališč v italijanskem delu tega gorovja (Poldini, 2002; Gobbo & Poldini, 2005). Precej redka v flori Julijskih Alp je tudi vrsta *Astragalus onobrychis*, ki je sicer diagnostična za kontinentalna suha travišča in vzhodnoevropske stepe iz reda *Festucetalia valesiacae*. Feoli Chiapella & Poldini (1993) jo uvrščata med razlikovalnice podzveze *Centaurenion dichroanthae* in sta jo popisala v sestojih asociacij *Bupleuro-Brometum condensati* in *Saturejo variegatae-Brometum condensati* v prigorju Furlanskih Alp. Ta grahovec je v Lepeni prvi opazil Brane Anderle (19. 7. 1995; v Dakskobler *et al.,* v pripravi), v letu 2008 pa smo ga popisali na dveh krajih (Trebež, Za Otoki, popisa 8 in 11 v Tabeli 1). Tudi drugod v Sloveniji je po nam znanih podatkih malo nahajališč (Sl. 6).



Sl. 6: Razširjenost vrste** Astragalus onobrychis **v Sloveniji. (Vira: Jogan** et al., **2001; FloVegSi, Biološki inštitut ZRC SAZU).
Fig. 6: Distribution of** Astragalus onobrychis **in Slovenia. (Sources: Jogan** et al., **2001; Database FloVegSi, Institute of Biology, SRC SASA).

Zaradi naštetih redkih ali ogroženih vrst obravnavani travniki vsekakor zaslužijo našo pozornost in ustrezno obravnavo. Kot habitatni tip polnaravna suha travišča in grmiščne faze na karbonatnih tleh *(Festuco-Brometea)* – pomembna rastišča kukovičevk, pa ti travniki sodijo tudi med evropsko pomembne habitatne tipe v okviru omrežja Natura 2000 (Leskovar & Jogan, 2004), kar je dodaten razlog, da jih zavarujemo.

Predlogi za varovanje

Travnike Za Otoki (kjer je bogato nahajališče vrste *Orchis coriophora)* zdaj kosijo člani Lovske družine Soča (Završnik, 2008). Ob njih poteka naravoslovna učna pot, imenovana Soška pot, ki se začne pri izviru Soče in se pri Kršovcu priključi bovškim sprehajalnim potem. Travnikov in pašnikov na nahajališču Trebež na levem bregu Lepenice (nasproti kampa Klin, tam sta nahajališči vrst *Herminium monorchis* in *Astragalus onobrychis)* ne kosijo več. Predlagamo, da Uprava Triglavskega narodnega parka ustrezno spodbudi lastnike parcel, da bi dovolili oz. nadaljevali vsakoletno pozno košnjo (ne prej kot v drugi polovici julija) teh obrečnih travnikov oz. da ustrezno spodbuja tistega, ki to košnjo že zdaj opravlja (Lovsko družino Soča). Če košnjo opustimo, se bodo opisani travniki razmeroma hitro zarasli (verjetno s pionirskim smrekovim gozdom), pri tem pa bodo najbolj ogrožene kukavičevke, tudi vrsti *Herminium monorchis* in *Orchis coriophora*. Obiskovalci (pohodniki) najbrž že opažajo bogato cvetano teh travnikov, čeprav je v času največjega obiska (poletni meseci, julij, avgust, prva polovica septembra) manj očitna kot npr. maja in junija. Vprašanje pa je, ali je nanjo smiselno še posebej opozoriti (npr. z informacijsko tablo). Zaradi majhnih površin bi bil povečan obisk ljubiteljev (fotografiranje) za te travnike najbrž preveč moteč. Predlagamo tudi vsakoletno spremljanje stanja populacije kukavičevk na Trebežu in Za Otoki, kar še posebej velja za populacijo vrste *Orchis coriophora*. Tako bomo preverjali, kako vsakoletna košnja in drugi morebitni posegi vplivajo na njeno številčnost. Vnos dodatnih hranil (gnojenje) naj bo na teh površinah prepovedan. Menimo, da so v tem prispevku opisane posebnosti rastlinstva in rastja na travnikih pri vasi Soča dovolj tehten razlog, da pristojne službe z ustreznimi posegi zagotovijo njihovo ohranitev in čim boljše razmere za uspevanje kukavičevk tudi v prihodnje.

ZAKLJUČKI

Floristično in fitocenološko smo analizirali suhe travnike na rečnih nanosih pri vasi Soča: Trebež na levem bregu Lepenice pri sotočju s Sočo, Za Otoki na levem bregu Soče po toku navzdol od tega sotočja (Julijske Alpe, Triglavski narodni park). Ugotovili smo, da te travnike lahko uvrstimo v tri asociacije: *Ranunculo bulbosi-Arrhenatheretum elatioris, Centaureo dichroanthae-Globularietum cordifoliae* in *Gentianello pilosae-Brometum erecti* ass. nov. hoc loco, pri čemer prevladujejo sestoji slednje. V njih smo doslej popisali 171 praprotnic in semenk, med njimi jih je 10 v Sloveniji zavarovanih, 11 pa uvrščenih v njen Rdeči seznam. Dveh popisanih taksonov, *Astragalus onobrychis* in *Plantago argentea* subsp. *liburnica*, doslej v flori slovenskega dela Julijskih Alp sploh še nismo poznali. Med zavarovanimi oz. ogroženimi rastlinskimi taksoni jih je največ iz družine kukavičevk *(Orchidaceae),* med njimi redka vrsti *Herminium monorchis* in *Orchis coriophora*. Preučeni travniki sodijo v evropsko varstveno pomemben habitatni tip polnaravna suha travišča na karbonatnih tleh *(Festuco-Brometea).* Predlagamo, da upravljavec tega prostora, Triglavski narodni park, spodbudi lastnike teh travnikov, da dovolijo oz. nadaljujejo vsakoletno pozno košnjo (ne prej kot sredi julija), in podpre Lovsko družino Soča, ki to košnjo že zdaj opravlja na parcelah Za Otoki.

ZAHVALA

Prisrčno se zahvaljujeva dr. Amadeju Trnkoczyju za spremstvo na terenu in pomoč pri določanju rastlin, Branetu Dolinarju za nasvete in podatke o vrsti *Orchis coriophora,* Iztoku Sajku za izdelavo preglednega zemljevida (Sl. 1) in dvema neimenovanima ocenjevalcema za koristne opombe, nasvete in popravke. Raziskavo smo opravili v okviru projekta Biodiverziteta Posočja in naravovarstvene aplikacije za območja Natura 2000, ki ga je financirala Javna agencija za raziskovalno dejavnost Republike Slovenije in SAZU.

Tab. 1: Obrečna travišča pri vasi Soča (Julijske Alpe, 9647/4). Okrajšave: Al: rečni nanosi; Fl: obrečna tla (fluvisol), Re: rendzina.

Tab. 1: Riverine meadows near the village of Soča (the Julian Alps, 9647/4). Abreviations: Al: alluvium; Fl: fluvisols; Re: rendzina (rendzic leptosol).

1: *Ranunculo bulbosi-Arrhenatheretum elatioris* Ellmauer in Ellmauer & Mucina 1993
2–10: *Gentianello pilosae-Brometum erecti* ass. nov. hoc loco
11–12: *Centaureo dichroanthae-Globularietum cordifoliae* Pignatti 1953

	Zaporedna številka popisa (Number of relevé)		1	2	3	4	5	6	7	8	9	10	11	12		
	Delovna številka popisa (Working number)		215367	218017	218015	218016	221393	221394	221395	220618	221391	221392	220619	218008		
	Nadmorska višina v m (Altitude in m)		425	440	440	440	425	425	430	433	440	440	425	430		
	Lega (Aspect)		0	0	0	0	0	0	0	0	0	0	0	0		
	Nagib v stopinjah (Slope in degrees)		0	0	0	0	0	0	0	0	0	0	0	0		
	Matična podlaga (Parent material)		Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al		
	Tla (Soil)		Re	Re	Re	Re	Re	Re	Fl	Re	Re	Re	Re	Re		
	Kamnitost v % (Stoniness in %)		0	0	0	0	0	0	0	0	0	0	20	0		
	Zastiranje v % (Cover in %):															
	Zeliščna plast (Herb layer)	E1	100	90	90	90	100	100	100	100	100	100	80	100		
	Mahovna plast (Moss layer)	E0	0	2	2	2	0	0	0	0	5	5	10	2		
	Velikost popisne ploskve (Relevé area)	m^2	20	20	20	20	20	20	20	20	20	20	20	10		
	Število vrst (Number of species)		61	40	63	59	65	57	60	72	58	48	44	58		
	Datum popisa (Date of taking relevé)		9.5.07	9.5.07	9.5.07	9.5.07	19.6.08	19.6.08	19.6.08	19.6.08	19.6.08	19.6.08	19.6.08	9.5.07		
	Nahajališče (Locality)		Soča - Za Otoki	Soča - Za Otoki	Soča - Za Otoki	Soča - Za Otoki	Soča - Za Otoki	Soča - Za Otoki	Soča - Za Otoki	Lepena - Trebež	Lepena - Trebež	Lepena - Trebež	Soča - Za Otoki	Soča- Podklanec		
	Razlikovalne vrste sintaksonov (Differential species of the syntaxa)														Pr.	Fr.
MA	*Poa pratensis*	E1	2	.	.	.	.	.	.	.	.	.	.	.	1	8
MA	*Trisetum flavescens*	E1	1	.	.	.	.	.	.	.	.	.	.	.	1	8
MA	*Arrhenatherum elatius*	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
FB	*Ranunculus bulbosus*	E1	+	.	+	.	+	.	.	+	+	.	.	.	5	42
QP	*Primula veris* subsp. *columnae*	E1	.	1	+	+	1	+	.	+	+	+	.	.	8	67
SCh	*Plantago holosteum*	E1	.	.	+	+	+	.	.	3	3	3	.	+	7	58
FB	*Orchis militaris*	E1	.	+	+	1	+	+	+	.	.	.	.	.	6	50
ES	*Ranunculus carinthiacus*	E1	+	.	+	.	.	+	.	+	+	+	.	.	6	50
MA	*Orchis coriophora* subsp. *coriophora*	E1	.	+	1	1	1	+	.	.	.	.	.	.	5	42
FB	*Gentianella pilosa*	E1	.	.	2	1	1	r	.	.	+	.	.	.	5	42
ES	*Globularia cordifolia*	E1	.	.	+	+	.	.	.	+	.	.	3	+	5	42
ES	*Sesleria caerulea* subsp. *calcaria*	E1	.	.	.	.	.	.	.	.	.	.	3	2	2	17
TR	*Gypsophila repens*	E1	.	.	.	.	.	.	.	.	.	.	3	+	2	17
TR	*Hieracium porrifolium*	E1	.	.	.	.	.	.	.	.	.	.	1	+	2	17
SCh	*Centaurea dichroantha*	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
SCh	***Scorzonero-Chrysopogonetalia***															
	Sanguisorba minor subsp. *muricata*	E1	+	+	+	+	+	+	+	+	1	+	+	+	12	100
	Centaurea scabiosa subsp. *fritschii*	E1	.	.	+	.	+	1	1	.	.	.	.	+	5	42
	Plantago argentea subsp. *liburnica*	E1	.	.	+	.	.	.	+	.	.	+	.	.	3	25
FB	***Festuco-Brometea***															
	Bromus erectus s. str. *(= Bromopsis erecta)*	E1	+	3	3	3	4	3	3	3	3	3	1	2	12	100
	Koeleria pyramidata	E1	1	1	3	3	2	2	3	2	2	3	2	2	12	100

	Zaporedna številka popisa (Number of relevé)		1	2	3	4	5	6	7	8	9	10	11	12		
	Festuca rupicola	E1	1	2	2	2	+	1	1	1	1	2	+	1	12	100
	Brachypodium rupestre	E1	+	+	+	1	2	2	3	2	1	3	+	+	12	100
	Pimpinella saxifraga	E1	1	1	1	1	1	+	+	+	1	1	+	+	12	100
	Carlina acaulis	E1	+	+	+	+	+	+	.	1	1	+	1	+	11	92
	Galium verum	E1	+	+	1	+	1	1	+	+	+	.	1	1	11	92
	Plantago media	E1	1	1	1	1	1	1	1	1	1	1	.	.	10	83
	Prunella grandiflora	E1	.	.	1	+	1	+	+	1	+	+	+	+	10	83
	Briza media	E1	+	.	1	1	1	1	1	+	1	1	.	.	9	75
	Carex caryophyllea	E1	+	1	1	1	+	+	+	+	.	.	.	+	9	75
	Hippocrepis comosa	E1	+	+	+	1	.	.	+	+	1	+	.	+	9	75
	Medicago lupulina	E1	+	.	+	+	+	1	1	+	+	+	.	.	9	75
	Polygala comosa	E1	1	.	1	1	+	+	1	+	+	+	.	.	9	75
	Silene nutans	E1	+	+	.	+	+	+	+	+	+	+	.	.	9	75
	Silene vulgaris	E1	+	.	+	+	+	+	+	+	+	+	.	.	9	75
	Campanula rotundifolia	E1	1	.	1	+	+	+	1	+	.	+	.	.	8	67
	Scabiosa columbaria	E1	+	.	+	+	.	+	+	+	+	.	+	.	8	67
	Orchis ustulata	E1	.	+	+	1	+	+	1	.	1	1	.	.	8	67
	Campanula glomerata	E1	.	+	r	.	+	+	+	r	.	+	.	.	7	58
	Salvia pratensis	E1	.	+	+	1	+	1	1	.	1	.	.	.	7	58
	Linum catharticum	E1	.	.	1	1	+	.	.	+	+	.	.	1	6	50
	Peucedanum oreoselinum	E1	.	.	+	.	+	1	1	.	1	.	.	1	6	50
	Allium carinatum subsp. *carinatum*	E1	.	.	.	.	.	+	+	+	+	.	+	+	6	50
	Euphorbia cyparissias	E1	.	+	1	.	.	.	.	1	+	.	+	.	5	42
	Trifolium montanum	E1	.	.	.	.	+	.	+	+	+	+	.	.	5	42
	Ononis spinosa	E1	+	.	.	+	+	.	.	.	.	.	.	.	3	25
	Euphrasia stricta	E1	.	.	+	.	.	.	.	+	.	.	+	.	3	25
	Carex humilis	E1	.	.	.	.	.	.	.	.	1	.	2	2	3	25
	Potentilla pusilla	E1	.	.	.	.	.	.	.	.	+	.	+	+	3	25
	Arabis hirsuta	E1	+	.	.	.	.	.	+	.	.	.	.	.	2	17
	Asperula cynanchica	E1	.	.	+	.	.	.	.	+	.	.	.	.	2	17
	Astragalus onobrychis	E1	.	.	.	.	.	.	.	1	.	.	1	.	2	17
	Teucrium montanum	E1	.	.	.	.	.	.	.	.	+	.	+	.	2	17
	Cuscuta epithymum	E1	.	.	.	.	.	.	.	.	.	+	+	.	2	17
	Carex praecox	E1	3	.	.	.	.	.	.	.	.	.	.	.	1	8
	Leontodon autumnalis	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
	Hieracium pilosella	E1		+	.	.	.	.	.	.	.	.	.	.	1	8
	Carlina vulgaris	E1	.	.	.	+	.	.	.	.	.	.	.	.	1	8
	Filipendula vulgaris	E1	.	.	.	.	.	.	.	+	.	.	.	.	1	8
	Orobanche gracilis	E1	.	.	.	.	.	.	.	r	.	.	.	.	1	8
	Gentianella ciliata	E1	.	.	.	.	.	.	.	.	r	.	.	.	1	8
	Rhinanthus freynii	E1	.	.	.	.	.	.	.	.	1	.	.	.	1	8
	Genista tinctoria	E1	.	.	.	.	.	.	.	.	.	+	.	.	1	8
	Dianthus monspessulanus	E1	.	.	.	.	.	.	.	.	.	+	.	.	1	8
	Hypochoeris maculata	E1	.	.	.	.	.	.	.	.	.	r	.	.	1	8
	Allium senescens	E1	.	.	.	.	.	.	.	.	.	.	+	.	1	8
	Selaginella helvetica	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
MC	***Molinion caeruleae***															
	Gymnadenia conopsea	E1	.	.	+	+	+	+	.	+	1	+	.	1	8	67
	Ophioglossum vulgatum	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
	Molinia caerulea subsp. *caerulea*	E1	.	.	+	.	.	.	.	.	.	.	.	.	1	8
	Carex distans	E1	.	.	.	.	.	.	r	.	.	.	.	.	1	8
	Carex tomentosa	E1	.	.	.	.	.	.	+	.	.	.	.	.	1	8
	Sanguisorba officinalis	E1	.	.	.	.	.	.	+	.	.	.	.	.	1	8
	Herminium monorchis	E1	.	.	.	.	.	.	.	.	+	.	.	.	1	8
MA	***Molinio-Arrhenatheretea***															
	Leontodon hispidus	E1	1	1	+	1	+	1	1	1	1	+	.	+	11	92
	Lotus corniculatus	E1	1	1	1	1	1	1	1	.	1	1	+	1	11	92

	Zaporedna številka popisa (Number of relevé)		1	2	3	4	5	6	7	8	9	10	11	12		
	Dactylis glomerata	E1	1	+	1	+	1	1	.	1	1	1	.	.	9	75
	Trifolium pratense	E1	1	.	1	1	1	1	1	+	+	+	.	.	9	75
	Centaurea jacea	E1	.	+	+	+	+	1	.	+	+	.	+	+	9	75
	Achillea millefolium	E1	1	.	+	1	1	1	1	+	.	+	.	.	8	67
	Galium mollugo	E1	1	+	.	r	+	1	1	+	+	.	.	.	8	67
	Helictotrichon pubescens	E1	2	+	.	+	+	2	1	+	.	+	.	.	8	67
	Rhinanthus minor	E1	+	.	+	.	.	+	1	1	1	1	.	.	7	58
	Trifolium repens	E1	+	.	+	r	+	+	.	.	+	+	.	.	7	58
	Vicia cracca	E1	+	+	r	+	1	1	1	.	.	.	.	.	7	58
	Prunella vulgaris	E1	.	+	1	1	.	.	+	+	1	1	.	.	7	58
	Leucanthemum ircutianum	E1	.	.	1	.	+	1	.	+	+	+	.	.	6	50
	Plantago lanceolata	E1	1	+	+	.	+	+	.	.	.	.	.	.	5	42
	Ranunculus acris	E1	1	.	.	+	.	+	1	+	.	.	.	.	5	42
	Euphrasia rostkoviana	E1	+	.	+	.	.	+	.	.	r	.	+	.	5	42
	Lathyrus pratensis	E1	+	+	.	.	+	.	+	+	.	.	.	.	5	42
	Ranunculus nemorosus	E1	+	+	.	.	.	+	+	.	.	.	.	.	4	33
	Rumex acetosa	E1	1	.	.	.	.	+	+	+	.	.	.	.	4	33
	Tragopogon pratensis	E1	.	.	+	.	+	1	1	.	.	.	.	.	4	33
	Festuca pratensis	E1	1	.	.	.	+	.	+	.	.	.	.	.	3	25
	Luzula campestris	E1	.	+	.	.	+	.	.	.	+	.	.	.	3	25
	Carex hirta	E1	+	.	+	.	.	.	.	.	.	.	.	.	2	17
	Achillea roseoalba	E1	.	.	.	.	.	1	+	.	.	.	.	.	2	17
	Festuca rubra agg.	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
	Cerastium holosteoides	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
	Potentilla reptans	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
	Veronica chamaedrys	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
SM	*Myosotis arvensis*	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
	Trifolium campestre	E1	.	.	.	.	+	.	.	.	.	.	.	.	1	8
	Knautia arvensis	E1	.	.	.	.	r	.	.	.	.	.	.	.	1	8
	Festuca arundinacea	E1	.	.	.	.	.	+	.	.	.	.	.	.	1	8
	Heracleum sphondylium	E1	.	.	.	.	.	.	+	.	.	.	.	.	1	8
	Pimpinella major	E1	.	.	.	.	.	.	+	.	.	.	.	.	1	8
	Allium scorodoprasum	E1	.	.	.	.	.	.	.	r	.	.	.	.	1	8
	Stellaria graminea	E1	.	.	.	.	.	.	.	+	.	.	.	.	1	8
ES	***Elyno-Seslerietea***															
	Helianthemum nummularium subsp. *grandiflorum*	E1	+	1	2	1	2	+	+	1	1	.	1	1	11	92
	Thymus praecox subsp. *polytrichus*	E1	+	.	+	+	+	.	+	1	1	1	1	1	10	83
	Betonica alopecuros	E1	.	.	.	+	+	.	+	+	.	.	.	+	5	42
	Galium anisophyllon	E1	+	.	.	+	.	.	+	+	.	.	.	.	4	33
	Allium ericetorum	E1	.	.	.	+	.	.	.	.	.	.	.	+	2	17
	Rhinanthus glacialis	E1	.	.	.	+	.	.	.	.	.	.	.	1	2	17
	Alchemilla glaucescens ?	E1	.	.	.	.	.	.	.	+	.	+	.	.	2	17
	Carex mucronata	E1	.	.	.	.	.	.	.	.	.	.	+	+	2	17
	Gentiana verna	E1	.	.	+	.	.	.	.	.	.	.	.	.	1	8
	Hieracium valdepilosum	E1	.	.	.	+	.	.	.	.	.	.	.	.	1	8
	Hieracium villosum	E1	.	.	.	.	.	.	+	.	.	.	.	.	1	8
	Festuca calva	E1	.	.	.	.	.	.	.	+	.	.	.	.	1	8
	Phyteuma orbiculare	E1	.	.	.	.	.	.	.	+	.	.	.	.	1	8
	Gentiana clusii	E1	.	.	.	.	.	.	.	.	.	.	.	1	1	8
	Euphrasia salisburgensis	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
	Gymnadenia odoratissima	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
CU	***Calluno-Ulicetea***															
	Potentilla erecta	E1	+	1	.	+	+	+	+	.	+	+	.	+	9	75
KC	***Koelerio-Corynephoretea***															
	Cardaminopsis arenosa	E1	+	+	.	.	+	.	+	.	.	.	.	.	4	33
	Petrorhagia saxifraga	E1	+	.	.	.	.	.	.	+	.	.	.	.	2	17
	Sedum sexangulare	E1	.	.	.	.	+	.	.	+	.	.	.	.	2	17

	Zaporedna številka popisa (Number of relevé)		1	2	3	4	5	6	7	8	9	10	11	12		
	Cerastium brachypetalum	E1	.	.	.	.	.	+	.	+	.	.	.	.	2	17
	Arenaria serpyllifolia	E1	+	.	.	.	.	.	.	.	.	.	.	.	1	8
TG	***Trifolio-Geranietea***															
	Thalictrum minus	E1	.	.	.	.	+	+	+	.	.	.	.	+	4	33
	Vincetoxicum hirundinaria	E1	.	.	.	.	.	.	.	+	.	+	+	+	4	33
	Anthericum ramosum	E1	.	.	.	.	.	.	.	.	.	.	.	1	1	8
SCf	***Scheuchzerio-Caricetea fuscae***															
	Parnassia palustris	E1	.	.	r	+	+	.	.	.	.	.	.	.	3	25
	Carex panicea	E1	.	.	.	.	.	.	+	.	.	.	.	.	1	8
TR	***Thlaspietea rotundifolii***															
	Biscutella laevigata	E1	+	1	1	1	+	.	.	+	1	+	+	+	10	83
	Hieracium piloselloides	E1	.	.	r	+	.	.	.	.	.	.	+	+	4	33
	Leontodon hispidus subsp. *hyoseroides ?*	E1	.	.	.	.	.	.	.	+	+	+	1	.	4	33
	Silene hayekiana	E1	.	.	.	.	.	.	.	+	+	+	+	.	4	33
	Rumex scutatus	E1	.	.	.	.	+	.	.	+	+	.	.	.	3	25
	Hieracium glaucum	E1	.	.	.	.	.	.	.	.	+	.	+	+	3	25
	Petasites paradoxus	E1	.	.	.	.	+	.	.	+	.	.	.	.	2	17
	Dianthus sternbergii	E1	.	.	.	+	.	.	.	.	.	.	.	.	1	8
	Campanula cespitosa	E1	.	.	.	.	.	.	.	.	.	.	1	.	1	8
	Achnatherum calamagrostis	E1	.	.	.	.	.	.	.	.	.	.	+	.	1	8
	Leontodon berinii	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
	Salix eleagnos	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
	Seseli gouanii	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
EP	***Erico-Pinetea, Vaccinio-Piceetea***															
	Molinia caerulea subsp. *arundinacea*	E1	.	.	.	.	+	+	+	+	.	.	+	.	5	42
	Epipactis atrorubens	E1	.	.	.	.	+	.	.	.	.	.	+	+	3	25
	Aster amellus	E1	.	.	.	+	.	.	.	.	.	.	.	+	2	17
VP	*Picea abies*	E1	.	.	.	.	.	.	.	+	.	.	.	r	2	17
	Erica carnea	E1	.	.	.	.	.	.	.	.	.	.	1	2	2	17
	Chamaecytisus purpureus	E1	.	1	.	.	.	.	.	.	.	.	.	1	2	17
	Polygala nicaeensis subsp. *forojulensis*	E1	.	+	.	.	.	.	.	.	.	.	.	.	1	8
	Calamagrostis varia	E1	.	.	.	.	+	.	.	.	.	.	.	.	1	8
	Carex ornithopoda	E1	.	.	.	.	.	.	.	.	.	.	+	.	1	8
	Pinus sylvestris	E1	.	.	.	.	.	.	.	.	.	.	+	.	1	8
	Genista radiata	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
	Arctostaphylos uva-ursi	E1	.	.	.	.	.	.	.	.	.	.	.	r	1	8
QP	***Quercetalia pubescentis***															
	Carex flacca	E1	.	.	.	+	.	.	.	+	.	.	.	+	3	25
	Valeriana collina	E1	.	.	.	.	.	.	.	+	.	.	.	.	1	8
	Fraxinus ornus	E1	.	.	.	.	.	.	.	.	.	.	.	+	1	8
QF	***Querco-Fegetea***															
	Cruciata glabra	E1	+	+	.	.	+	.	+	+	+	+	.	.	7	58
	Knautia drymeia	E1	.	.	.	.	.	+	.	.	.	.	.	.	1	8
	Listera ovata	E1	.	.	.	.	.	.	.	+	.	.	.	.	1	8
O	**Druge vrste (Other species)**															
	Phalaris arundinacea	E1	+	.	r	.	.	.	.	.	.	.	.	.	2	17
	Salix cinerea	E1	.	.	.	.	.	+	.	.	.	.	.	.	1	8
	Bromus sp.	E1	.	.	.	.	.	.	.	.	.	+	.	.	1	8
	Juniperus communis	E1	.	.	.	.	.	.	.	.	.	.	r	.	1	8
ML	**Mahovi in lišaji (Mosses and lichens)**															
	Tortella sp.	E0	.	+	+	+	.	.	.	.	.	.	.	.	3	25
	Rhytidium rugosum	E0	.	.	+	.	.	.	.	.	1	1	.	.	3	25
	Thuidium abietinum	E0	.	.	+	+	.	.	.	.	.	.	.	.	2	17
	Tortella tortuosa	E0	.	.	.	.	.	.	.	.	.	.	2	+	2	17
	Rhytidiadelphus triquetrus	E0	.	.	.	.	.	.	.	.	.	.	.	+	1	8

Tab. 2: Submontanska in montanska (pol)suha travišča v Furlaniji, Sloveniji in na Hrvaškem z dominantno vrsto *Bromus erectus*.
Tab. 2: Submontane and montane meadows in Friuli, Slovenia and Croatia with dominant species *Bromus erectus*.

1: *Avenulo praeustae-Brometum erecti* (Feoli Chiapella & Poldini, 1993, tabela 8)
2: *Onobrychido arenariae-Brometum erecti* (Feoli Chiapella & Poldini, 1993, tabela 6)
3: *Gentianello pilosae-Brometum erecti* ass. nov. hoc loco
4: *Scabioso hladnikianae-Caricetum humulis* (Škornik, 2003, tabela 1, stolpec 1)
5: *Bromo-Plantaginetum mediae* (Šugar, 1972, tab. 20, popisi 1 do 22)
6: *Scabios hladnikianae-Caricetum humilis* (Tomažič, 1941, 79)

	Zaporedna številka (Successive number)		1	2	3	4	5	6
	Število popisov (Number of relevés)		8	46	9	39	22	12
	Avtor (Author)		FCP	FCP	ID	SŠ	IŠ	GT
	Razlikovalnice asociacije *Avenulo-Brometum* (Differential species of the ass.)							
SCh	*Helictotrichon praeustum*	E1	63	2	.	.	.	.
PT	*Traunsteinera globosa*	E1	63	7	.	.	.	.
	Razlikovalnice asociacije *Onobrychido-Brometum* (Differential species of the ass.)							
FB	*Rhinanthus freynii*	E1	13	63	11	.	.	.
FB	*Onobrychis arenaria*	E1	.	26	.	.	.	.
	Razlikovalnice asociacije *Gentianello-Brometum* (Differential species of the ass.)							
QP	*Primula veris* subsp. *columnae*	E1	.	.	89	.	.	.
SCh	*Plantago holosteum*	E1	25	.	67	.	.	.
FB	*Orchis militaris*	E1	.	.	67	.	.	.
FB	*Gentianella pilosa*	E1	.	.	56	.	.	.
MA	*Orchis coriophora* subsp. *coriophora*	E1	.	.	56	.	.	.
ES	*Ranunculus carinthiacus*	E1	.	.	56	.	.	.
	Razlikovalnice asociacije *Scabioso-Caricetum humilis* (Differential species of the ass.)							
EP	*Genista januensis*	E1	.	.	.	77	64	90
EP	*Leontodon incanus*	E1	.	.	.	74	55	90
ES	*Acinos alpinus*	E1	.	2	.	62	.	90
TG	*Veronica jacquinii*	E1	.	.	.	59	59	70
FB	*Scabiosa hladnikiana*	E1	.	.	.	46	27	90
SCh	***Scorzonero-Chrysopogonetalia***							
	Knautia ressmannii	E1	75	50	.	.	.	.
	Centaurea jacea subsp. *gaudinii*	E1	50	30	.	.	.	.
	Centaurea scabiosa subsp. *fritschii*	E1	38	69	44	85	86	50
	Plantago argentea subsp. *liburnica*	E1	38	9	33	.	.	.
	Pseudolysimachion barrelieri	E1	25	2	.	.	.	90
	Scorzonera villosa	E1	13	13	.	.	.	.
	Bupleurum ranunculoides	E1	13	4	.	.	.	.
	Chrysopogon gryllus	E1	.	28	.	.	.	.
	Galium lucidum	E1	.	4	.	.	.	.
	Potentilla australis	E1	.	2	.	.	.	.
	Knautia illyrica	E1	.	2	.	.	.	.
	Scorzonera austriaca	E1	.	2	.	.	.	.
	Gentiana tergestina	E1	.	.	.	5	.	.
FB	***Festuco-Brometea***							
	Bromus erectus s. lat.	E1	100	100	100	85	100	90
	Briza media	E1	100	93	89	92	68	50
	Peucedanum oreoselinum	E1	100	72	56	79	45	90
	Carex montana	E1	100	22	.	67	.	.
	Koeleria pyramidata	E1	88	80	100	100	100	30
	Brachypodium rupestre	E1	88	93	100	82	36	50
	Galium verum	E1	88	74	89	46	23	50
	Filipendula vulgaris	E1	88	63	11	5	23	10
	Cirsium pannonicum	E1	88	48	.	67	59	30

Zaporedna številka (Successive number)		1	2	3	4	5	6
Carlina acaulis	E1	75	22	89	62	.	.
Trifolium montanum	E1	75	70	56	79	55	.
Euphorbia verrucosa	E1	75	61	.	62	59	50
Festuca rupicola (inc. *F. valesiaca* agg.)	E1	50	67	100	87	23	10
Prunella grandiflora	E1	50	24	89	49	36	90
Hypochoeris maculata	E1	50	24	11	49	55	10
Buphthalmum salicifolium	E1	50	59	.	87	95	90
Thymus pulegioides	E1	50	37	.	67	95	10
Plantago media	E1	38	61	100	82	86	70
Carex caryophyllea	E1	38	39	78	87	.	90
Euphorbia cyparissias	E1	38	22	44	67	68	70
Carex humilis	E1	38	7	11	36	45	90
Hieracium pilosella	E1	38	7	11	26	.	.
Genista tinctoria	E1	38	28	11	10	.	.
Teucrium chamaedrys	E1	38	20	.	64	23	90
Betonica officinalis (inc. *B. serotina)*	E1	38	43	.	13	9	70
Globularia punctata	E1	38	15	.	82	73	90
Festuca valesiaca	E1	38	2	.	.	.	.
Salvia pratensis s. lat.	E1	25	76	78	62	41	50
Arabis hirsuta	E1	25	2	11	10	9	.
Linum viscosum	E1	25	17	.	13	14	10
Danthonia alpina	E1	25	17	.	.	.	10
Anthyllis vulneraria s. lat.	E1	25	39	.	85	82	70
Asphodelus albus	E1	25	.	.	.	.	.
Pimpinella saxifraga	E1	13	39	100	51	.	30
Hippocrepis comosa	E1	13	22	78	77	68	90
Campanula glomerata	E1	13	59	78	.	18	30
Linum catharticum	E1	13	54	56	67	73	.
Ononis spinosa	E1	13	46	22	.	.	.
Teucrium montanum	E1	13	11	11	28	9	90
Anacamptis pyramidalis	E1	13	20	.	18	.	10
Prunella laciniata	E1	13	4	.	27	18	10
Helianthemum nummularium s. lat.	E1	13	50	89	87	77	90
Centaurea triumfettii	E1	13	11	.	20	27	90
Gentiana cruciata	E1	13	4	.	.	.	10
Scabiosa gramuntia	E1	13	30	.	62	36	50
Trinia glauca	E1	13	.	.	.	.	.
Asperula cynanchica	E1	.	50	22	67	55	90
Sanguisorba minor s. lat.	E1	.	41	100	82	77	70
Silene nutans	E1	.	35	89	41	.	.
Medicago lupulina	E1	.	26	89	16	.	.
Polygala comosa	E1	.	24	89	85	41	.
Campanula rotundifolia	E1	.	24	78	.	.	.
Ranunculus bulbosus	E1		20	44	44	23	
Silene vulgaris	E1	.	20	89	23	55	.
Medicago falcata	E1	.	20	.	.	.	.
Allium carinatum subsp. *carinatum*	E1	.	15	44	.	18	.
Thlaspi praecox	E1	.	11	.	33	.	.
Dorycnium germanicum (inc. *D. herbaceum)*	E1	.	11	.	18	32	90
Orobanche gracilis	E1	.	9	11	13	.	.
Dianthus carthusianorum agg.	E1	.	4	.	59	41	10
Orchis ustulata	E1	.	2	89	21	.	.
Gentianella ciliata	E1	.	2	11	20	.	50
Orchis morio	E1	.	2	.	18	.	10
Orchis tridentata	E1	.	2	.	33	.	10
Erigeron acris	E1	.	2	.	.	.	30
Linum tenuifolium	E1	.	2	.	.	.	50
Scabiosa graminifolia	E1	.	2	.	.	.	.

	Zaporedna številka (Successive number)		1	2	3	4	5	6
	Scabiosa columbaria	E1	.	.	67	17	.	.
	Euphrasia stricta	E1	.	.	22	.	18	50
	Potentilla pusilla (inc. *P. verna* agg.)	E1	.	.	11	.	.	70
	Astragalus onobrychis	E1	.	.	11	.	.	.
	Cuscuta epithymum	E1	.	.	11	.	.	.
	Carlina vulgaris	E1	.	.	11	16	9	10
	Dianthus monspessulanus	E1	.	.	11	7	.	.
	Hieracium bauhinii	E1	.	.	.	33	55	.
	Gentianella germanica	E1	.	.	.	20	.	.
	Thesium linophyllon	E1	.	.	.	13	.	.
	Pulsatilla grandis	E1	.	.	.	10	.	.
	Ophrys insectifera	E1	.	.	.	8	.	.
	Botriochloa ishaemum	E1	.	.	.	8	.	10
	Potentilla recta	E1	.	.	.	7	.	.
	Linum flavum	E1	.	.	.	8	.	.
	Pulsatilla pratensis	E1	.	.	.	5	.	10
	Erysimum carniolicum	E1	.	.	.	.	23	.
	Allium carinatum subsp. *pulchellum*	E1	.	.	.	.	18	70
	Salvia verticillata	E1	.	.	.	.	18	.
	Ranunculus polyanthemos	E1	.	.	.	.	14	.
	Cirsium acaule	E1	.	.	.	.	9	.
	Potentilla heptaphylla	E1	.	.	.	.	9	.
	Thymus longicaulis	E1	.	.	.	.	.	90
	Knautia fleischmannii	E1	.	.	.	.	.	70
	Melica ciliata	E1	.	.	.	.	.	30
	Festuca pseudovina	E1	.	.	.	.	.	30
	Ophrys sphegodes	E1	.	.	.	.	.	10
	Spiranthis spiralis	E1	.	.	.	.	.	10
	Aster linosyris	E1	.	.	.	.	.	10
	Fumana procumbens	E1	.	.	.	.	.	10
MC	***Molinion caeruleae***							
	Gymnadenia conopsea	E1	88	.	78	46	9	.
	Serratula tinctoria	E1	75	2	.	.	.	.
	Succisa pratensis	E1	30	.	.	.	.	.
	Gladiolus palustris	E1	13	7	.	.	.	.
	Carex distans	E1	.	4	11	.	.	.
	Sanguisorba officinalis	E1	.	2	11	.	.	.
	Molinia caerulea subsp. *caerulea*	E1	.	.	11	.	.	.
	Carex tomentosa	E1	.	.	11	.	.	.
	Herminium monorchis	E1	.	.	11	.	.	.
PT	***Poo alpinae-Trisetalia***							
	Crocus vernus subsp. a*lbiflorus*	E1	100	4	.	.	.	.
	Trollius europaeus	E1	25	2	.	.	.	.
	Festuca nigrescens	E1	25	2	.	.	.	.
MA	***Molinio-Arrhenatheretea***							
	Lotus corniculatus s. lat.	E1	100	87	89	77	82	70
	Ranunculus nemorosus	E1	63	48	33	33	.	.
	Festuca rubra	E1	50	24	.	.	.	.
	Prunella vulgaris	E1	25	15	78	17	41	.
	Plantago lanceolata	E1	25	76	44	77	55	.
	Tragopogon pratensis	E1	25	65	44	.	.	.
	Muscari botryoides	E1	25	.	.	.	.	.
	Leontodon hispidus	E1	13	72	100	33	41	.
	Trifolium pratense	E1	13	54	89	23	18	.
	Lathyrus pratensis	E1	13	41	44	.	.	.
	Orobanche lutea	E1	13	4	.	5	.	.
	Laserpitium prutenicum	E1	13	4	.	.	.	.
	Ajuga reptans	E1	13	11	.	.	.	.

	Zaporedna številka (Successive number)		1	2	3	4	5	6
	Dactylis glomerata	E1	.	78	89	41	9	.
	Leucanthemum ircutianum	E1	.	65	67	44	41	.
	Achillea roseoalba	E1	.	43	22	.	.	.
	Arrhenatherum elatius	E1	.	43	.	16	14	.
	Centaurea jacea	E1	.	39	78	36	64	90
	Galium mollugo agg.	E1	.	37	78	13	45	90
	Holcus lanatus	E1	.	35	.	.	.	.
	Vicia cracca	E1	.	33	67	.	.	.
	Helictotrichon pubescens	E1	.	30	78	13	.	.
	Rumex acetosa	E1	.	30	33	.	.	.
	Centaurea carniolica	E1	.	26	.	.	.	.
	Festuca pratensis	E1	.	24	22	.	.	.
	Colchicum autumnale	E1	.	24	.	.	.	.
	Ranunculus acris	E1	.	22	44	.	.	.
	Veronica chamaedrys	E1	.	22	.	10	.	.
	Daucus carota	E1	.	22	.	.	23	.
	Poa pratensis	E1	.	22	.	.	.	.
	Centaurea nigrescens subsp. *transalpina*	E1	.	20	.	.	.	.
	Cerastium holosteoides	E1	.	17	.	.	.	.
	Trisetum flavescens	E1	.	15	.	.	.	.
	Taraxacum officinale	E1	.	11	.	.	.	.
	Pimpinella major	E1	.	10	11	.	.	.
	Achillea millefolium	E1	.	9	78	5	.	.
	Trifolium campestre	E1	.	9	11	.	.	.
	Knautia arvensis	E1	.	9	11	8	9	.
	Heracleum sphondylium	E1	.	9	11	.	.	.
	Senecio jacobea	E1	.	9	.	.	.	.
	Orobanche caryophyllea	E1	.	9	.	.	.	.
	Rhinanthus minor	E1	.	7	67	16	.	.
	Trifolium repens	E1	.	7	67	.	.	.
	Euphrasia rostkoviana	E1	.	7	33	.	.	.
	Festuca arundinacea	E1	.	7	11	.	.	.
	Carum carvi	E1	.	7	.	.	.	.
	Carex hirta	E1	.	4	11	.	.	.
	Luzula campestris	E1	.	.	33	17	.	.
	Allium scorodoprasum	E1	.	.	11	.	.	.
	Stellaria graminea	E1	.	.	11	.	.	.
ES	***Elyno-Seslerietea***							
	Sesleria caerulea subsp. *calcaria*	E1	88	2	.	.	.	70
	Betonica alopecuros	E1	75	4	44	8	.	.
	Leucanthemum heterophyllum	E1	75	4	.	.	.	.
	Phyteuma orbiculare	E1	50	4	11	30	.	.
	Gentiana lutea subsp. *symphyandra*	E1	50	.	.	.	.	.
	Gentiana clusii	E1	38	4	.	.	.	.
	Horminum pyrenaicum	E1	38	.	.	.	.	.
	Gentiana verna	E1	25	2	11	20	.	30
	Polygala alpestris	E1	25	17	.	.	.	.
	Pedicularis elongata	E1	25	4	.	.	.	.
	Allium ericetorum	E1	13	.	11	.	.	70
	Ranunculus venetus	E1	13	.	.	.	.	.
	Rhinanthus glacialis	E1	.	7	11	51	68	.
	Thymus praecox s. lat.	E1	.	4	78	.	.	.
	Globularia cordifolia	E1	.	2	33	10	.	90
	Galium anisophyllon	E1	.	.	33	.	.	.
	Alchemilla glaucescens	E1	.	.	22	7	.	.
	Hieracium valdepilosum	E1	.	.	11	.	.	.
	Hieracium villosum	E1	.	.	11	.	.	.
	Festuca calva	E1	.	.	11	.	.	.

	Zaporedna številka (Successive number)		1	2	3	4	5	6
	Dianthus sylvestris	E1	.	.	.	70	.	14
	Carex ornithopodioides	E1	.	.	.	27	.	.
	Gentiana urticulosa	E1	.	.	.	20	.	.
	Astre bellidiastrum	E1	.	.	.	10	.	.
	Campanula thyrsoides	E1	.	.	.	.	14	.
	Helianthemum alpestre	E1	.	.	.	.	.	30
CU	***Calluno-Ulicetea***							
	Genista germanica	E1	100	9	.	.	.	.
	Potentilla erecta	E1	75	41	78	28	9	.
	Anthoxanthum odoratum	E1	50	52	.	20	18	.
	Galium pumilum	E1	38	39	.	.	.	.
	Polygala vulgaris	E1	25	41	.	18	.	.
	Calluna vulgaris	E1	13	7	.	7	.	.
	Viola canina	E1	13	9	.	10	.	.
	Anntenaria dioica	E1	13	2	.	16	9	.
	Danthonia decumbens	E1	.	26	.	.	.	.
	Agrostis tenuis	E1	.	20	.	.	.	.
	Luzula multiflora	E1	.	20	.	.	.	.
	Carex pallescens	E1	.	20	.	.	.	.
	Phyteuma zahlbruckneri	E1	.	13	.	.	.	.
	Festuca filiformis	E1	.	11	.	.	.	.
	Coeloglossum viride	E1	.	7	.	.	.	.
	Arnica montana	E1	.	7	.	.	.	.
	Hypericum maculatum	E1	.	4	.	.	.	.
	Chamaespartium sagittale	E1	.	.	.	10	.	.
KC	***Koelerio-Corynephoretea***							
	Sedum sexangulare	E1	.	7	22	.	18	.
	Cardaminopsis arenosa	E1	.	.	33	.	.	.
	Cerastium brachypetalum	E1	.	.	22	.	.	.
	Petrorhagia saxifraga	E1	.	.	11	.	.	30
TG	***Trifolio-Geranietea***							
	Inula hirta	E1	100	13	.	18	18	90
	Thalictrum minus	E1	50	22	33	13	23	50
	Anthericum ramosum	E1	50	13	.	57	36	90
	Trifolium rubens	E1	50	35	.	.	.	.
	Galium x centroniae	E1	50	7	.	.	.	.
	Vincetoxicum hirundinaria	E1	38	9	22	.	.	.
	Iris graminea	E1	38	.	.	.	.	.
	Viola hirta	E1	25	26	.	8	9	50
	Verbascum nigrum	E1	25	2	.	.	.	.
	Pulmonaria australis	E1	25	.	.	.	.	.
	Lilium carniolicum	E1	13	.	.	10	.	.
	Thesium bavarum	E1	13	2	.	53	50	10
	Peucedanum cervaria	E1	13	22	.	10	.	.
	Laserpitium latifolium	E1	13	.	.	.	55	.
	Ferulago galbanifera	E1	.	11	.	.	.	.
	Stachys recta s. lat.	E1	.	7	.	31	32	70
	Hypericum perforatum	E1	.	4	.	7	.	.
	Geranium sanguineum	E1	.	4	.	33	41	.
	Clematis recta	E1	.	4	.	.	32	.
	Campanula rapunculus	E1	.	2	.	.	.	.
	Polygonatum odoratum	E1	.	2	.	.	.	.
	Laserpitium siler	E1	.	.	.	23	41	70
	Trifolium medium	E1	.	.	.	8	9	.
	Fragaria viridis	E1	.	.	.	7	.	.
	Fragaria moschata	E1	.	.	.	.	23	.
	Coronilla varia	E1	.	.	.	.	.	10

	Zaporedna številka (Successive number)		1	2	3	4	5	6
SCf	***Scheuchzerio-Caricetea fuscae***							
	Parnassia palustris	E1	13	2	33	.	.	.
	Tofieldia calyculata	E1	13	.	.	13	.	.
	Carex panicea	E1	.	.	11	.	.	.
TR	***Thlaspietea rotundifolii***							
	Biscutella laevigata	E1	25	2	78	10	.	90
	Hieracium piloselloides	E1	.	4	22	.	.	.
	Leontodon hispidus subsp. *hyoseroides ?*	E1	.	.	33	.	.	.
	Silene hayekiana	E1	.	.	33	.	.	.
	Rumex scutatus	E1	.	.	33	.	.	.
	Hieracium glaucum	E1	.	.	11	.	.	.
	Petasites paradoxus	E1	.	.	22	.	.	.
	Dianthus sternbergii	E1	.	.	11	.	.	.
EP	***Erico-Pinetea, Vaccinio-Piceetea***							
	Molinia caerulea subsp. *arundinacea*	E1	88	37	44	.	.	10
	Polygala chamaebuxus	E1	63	4	.	23	.	90
	Erica carnea	E1	50	2	.	10	27	70
	Crepis slovenica	E1	25	.	.	.	.	.
	Chamaecytisus hirsutus	E1	13	22	.	23	45	50
	Chamaecytisus purpureus	E1	.	4	11	.	.	90
	Carex ornithopoda	E1	.	4	.	8	.	.
	Carex alba	E1	.	2	.	5	.	.
	Epipactis atrorubens	E1	.	.	11	.	.	.
	Aster amellus	E1	.	.	11	10	.	.
VP	*Picea abies*	E1	.	.	11	.	.	.
	Polygala nicaeensis subsp. *forojulensis*	E1	.	.	11	.	.	.
	Calamagrostis varia	E1	.	.	11	.	.	50
QP	***Quercetalia pubescentis***							
	Carex flacca	E1	100	48	22	64	32	50
	Mercurialis ovata	E1	25	.	.	.	23	.
	Hypericum montanum	E1	13	2	.	.	.	.
	Valeriana collina	E1	.	2	11	.	.	.
	Tanacetum corymbosum	E1	.	.	.	13	18	.
	Campanula persicifolia	E1	.	.	.	.	9	.
FS	***Fagetalia sylvaticae***							
	Knautia drymeia	E1	13	30	11	51	.	.
	Lilium martagon	E1	.	.	.	10	.	.
	Mercurialis perennis	E1	.	.	.	.	9	.
QF	***Querco-Fegetea***							
	Cruciata glabra	E1	50	59	67	31	9	.
	Platanthera bifolia	E1	50	4	.	10	.	.
	Euphorbia angulata	E1	25	.	.	.	.	.
	Ornithogalum pyrenaicum	E1	.	9	.	.	.	.
	Primula vulgaris	E1	.	7	.	26	14	.
	Listera ovata	E1	.	4	11	.	.	.
	Lembotropis nigricans	E1	.	4	.	8	.	.
	Chamaecytisus supinus	E1	.	.	.	10	.	.
O	**Druge vrste (Other species)**							
	Erigeron annuus	E1	.	7	.	.	14	.
	Phalaris arundinacea	E1	.	.	11	.	.	.
	Salix cinerea	E1	.	.	11	.	.	.
	Bromus sp.	E1	.	.	11	.	.	.
	Picris hieracioides	E1	.	.	.	.	27	.
ML	**Mahovi in lišaji (Mosses and lichens)**							
	Tortella sp.	E0	.	.	33	.	.	.
	Rhytidium rugosum	E0	.	.	33	.	.	.
	Thuidium abietinum	E0	.	.	22	.	.	.

PHYTOSOCIOLOGICAL AND FLORISTIC ANALYSIS OF RIVERINE MEADOWS AT THE VILLAGE OF SOČA (THE JULIAN ALPS) AND PROPOSALS FOR THEIR PROTECTION

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SUMMARY

Applying the standard Central-European phytosociological method (Braun-Blanquet, 1964), the authors studied the dry meadows on fluvial deposits near the village of Soča (the Julian Alps, Triglav National Park), on the left bank of the Lepenica near the confluence with the Soča and in Za Otoki on the left bank of the Soča downstream from the confluence. With an analysis of 12 relevés, they classified these meadows into three associations. Stands of the associations Ranunculo bulbosi-Arrhenatheretum elatioris *(alliance* Arrhenatherion elatioris*, class* Molinio-Arrhenatheretea*) and* Centaureo dichroanthae-Globularietum cordifoliae *(alliance* Satureion subspicatae*, order* Scorzonero-Chrysopogonetalia*, class* Festuco-Brometea*) were determined only on small surfaces. Most of the relevés were, after comparison with similar (semi)dry meadows of Friuli, Slovenia and Croatia, classified into the new association* Gentianello pilosae-Brometum erecti *ass. nov. hoc loco (suballiance* Hypochoeridion maculatae*, alliance* Scorzonerion villosae*, order* Scorzonero-Chrysopogonetalia*, class* Festuco-Brometea, holotypus *is relevé No. 3 in Table 1). Its stands are characterised by certain diagnostic species of Illyrian-Submediterranean grasslands from the order* Scorzonero-Chrysopogonetalia *growing together with some diagnostic species of subalpine-alpine grasslands from the class* Elyno-Seslerietea*. Differential taxa of the new association are* Gentianella pilosa, Primula veris *subsp.* columnae, Plantago holosteum, Ranunculus carinthiacus, Orchis coriophora *subsp.* coriophora *and* O. militaris*. Their growing together indicates dealpine riverine dry grassland in an Alpine valley with a notable Submediterranean influence. 171 vascular plants have been recorded in the researched meadows so far. Ten of these species are protected in Slovenia and eleven are on the Red List of Slovenia. Until now, two of the taxa, namely* Astragalus onobrychis *and* Plantago argentea *subsp.* liburnica*, have not even been known in the flora of the Slovenian part of the Julian Alps. Most of the protected or endangered species come from the family of orchids (Orchidaceae), e.g.* Herminium monorchis *and* Orchis ustulata*. The most distinctive plant of these meadows is* Orchis coriophora *subsp.* coriophora*, an orchid whose decline has been considerable in Slovenia as well as elsewhere in Central Europe. The researched stands belong to a habitat type of semi-natural dry grasslands on calcareous soil (*Festuco-Brometea*) of European conservation concern. The authors propose that the manager of the area, Triglav National Park, should encourage the owners of these meadows to allow or continue their annual late mowing (not before mid-July) and support the Soča Hunting Society, whose members have already been mowing the plots of Za Otoki.*

Key words: phytosociology, (semi)dry meadows, *Festuco-Brometea*, *Orchis coriophora*, Natura 2000, the Julian Alps

LITERATURA

Aeschimann, D., K. Lauber, D. M. Moser & J.-P. Theurillat (2004): Flora alpina. Bd. 1, 2, 3. Haupt Verlag, Bern, Stuttgart, Wien, 1159 p. + 1188 p + 322 p.

Braun-Blanquet, J. (1964): Pflanzensoziologie. Grundzüge der Vegetationskunde. 3. Auflage. Springer, Wien, New York, 865 p.

Buser, S. (1986): Tolmač listov Tolmin in Videm (Udine). Osnovna geološka karta SFRJ 1 : 100000. Zvezni geološki zavod, Beograd, 103 str.

Buser, S. (1987): Osnovna geološka karta SFRJ. Tolmin in Videm 1 : 100000. Zvezni geološki zavod, Beograd.

Čušin, B. (2006): Rastlinstvo Breginjskega kota. Založba ZRC SAZU, Ljubljana, 198 str.

Dakskobler, I. (2001): Vrsta *Paradisea liliastrum* (L.) Bertol. v Krnskem pogorju (Julijske Alpe). Razprave 4. razreda SAZU, 42(2), 87–113.

Dakskobler, I. (2003a): Pionirsko smrekovje nad sedanjo (antropogeno) zgornjo gozdno mejo v južnih Julijskih Alpah (primer iz zgornje Baške doline). Hacquetia, 2(1), 19–52.

Dakskobler, I. (2003b): Floristične novosti iz Posočja in sosednjih območij v zahodni Sloveniji – III. Hladnikia, 15–16, 43–71.
Dakskobler, I. (2007): Fitocenološka in floristična analiza obrečnih gozdov v Posočju (zahodna Slovenija). Phytosociological and floristic analysis of riverine forests in the Soča Valley (western Slovenia). Razprave 4. razreda SAZU, 48(2), 25–138.
Dakskobler, I., W. R. Franz, G. Seljak (2005): Communities with *Eryngium alpinum* in the southern Julian Alps (Mts. Črna prst and Porezen). Hacquetia, 4(2), 83–120.
Dakskobler, I., B. Vreš & B. Anderle (2007): Novosti v flori slovenskega dela Julijskih Alp. Razprave 4. razreda SAZU, 48(2), 139–192.
Dakskobler, I., B. Vreš & B. Anderle (v pripravi): Novosti v flori Julijskih Alp (severozahodna Slovenija). Razprave 4. razreda SAZU.
Dolinar, B. (2001): Zadnja Trenta, vrt redkih orhidej. Moj mali svet, 33(5), 44–45.
Feoli Chiapella, L. & L. Poldini (1993): Prati e pascoli del Friuli (NE Italia) su substrati basici. Stud. Geobotanica, 13, 3–140.
Frahm, J. P. & W. Frey (1992): Moosflora. 3. Aufl. UTB. Eugen Ulmer, Stuttgart, 528 p.
Gobbo, G. & L. Poldini (2005): La diversità floristica del parco delle Prealpi Giulie. Atlante corologico. Università degli Studi di Trieste, Trieste, 364 p.
Jogan, N. (2007a): *Orchidaceae* – kukavičevke. V: Martinčič, A. et al. (ur.): Mala flora Slovenije. Ključ za določanje praprotnic in semenk. Tehniška založba Slovenije, Ljubljana, str. 756–784.
Jogan, N. (2007b): *Plantaginaceae* – trpotčevke. V: Martinčič, A. et al. (ur.): Mala flora Slovenije. Ključ za določanje praprotnic in semenk. Tehniška založba Slovenije, Ljubljana, str. 578–581.
Jogan, N., T. Bačič, B. Frajman, I. Leskovar, D. Naglič, A. Podobnik, B. Rozman, S. Strgulc Krajšek & B. Trčak (2001): Gradivo za Atlas flore Slovenije. Center za kartografijo favne in flore, Miklavž na Dravskem polju, 443 str.
Jogan, N., M. Kaligarič, I. Leskovar, A. Seliškar & J. Dobravec (2004): Habitatni tipi Slovenije HTS 2004. ARSO, Ljubljana, 64 str.
Jurkovšek, B. (1987a): Tolmač listov Beljak in Ponteba. Osnovna geološka karta SFRJ 1 : 100000. Zvezni geološki zavod, Beograd, 58 str.
Jurkovšek, B. (1987b): Osnovna geološka karta SFRJ. Beljak in Ponteba 1 : 100000. Zvezni geološki zavod, Beograd.
Kaligarič, M. (1997): Rastlinstvo Primorskega krasa in Slovenske Istre: travniki in pašniki. Knjižnica Annales Majora, Koper, 110 str.
Kaligarič, M. & S. Škornik (2002): Variety of dry and semi-dry secondary grasslands *(Festuco-Brometea)* in Slovenia – contact area of different geoelements. Razprave 4. razreda SAZU, 43(3), 227–246.
Leskovar, I. & N. Jogan (2004): Habitatni tipi in Natura 2000. Proteus, 66(9–10), 407–415.
Martinčič, A. (2003): Seznam listnatih mahov (Bryopsida) Slovenije. Hacquetia, 2(1), 91–166.
Martinčič, A., T. Wraber, N. Jogan, A. Podobnik, B. Turk, B. Vreš, V. Ravnik, B. Frajman, S. Strgulc Krajšek, B. Trčak, T. Bačič, M. A. Fischer, K. Eler & B. Surina (2007): Mala flora Slovenije. Ključ za določanje praprotnic in semenk. 4., dopolnjena in spremenjena izdaja. Tehniška založba Slovenije, Ljubljana, 968 str.
Mekinda-Majaron, T. (1995): Klimatografija Slovenije. Temperatura zraka 1961–1990. Hidrometeorološki zavod Republike Slovenije, Ljubljana, 356 str.
Perko, M. L. (2004): Die Orchideen Kärntens. Heimische Arten. Ikonographie, Verbreitung, ökologische Ansprüche, Gefährderung und Schutz. Arge Naturschutz, Klagenfurt, 320 p.
Podani, J. (2001): SYN-TAX 2000. Computer programs for data analysis in ecology and systematics. User's manual. Scientia, Budapest, 53 pp.
Poldini, L. (2002): Nuovo Atlante corologico delle piante vascolari nel Friuli Venezia Giulia. Regione FVG, Az. Parchi e Foreste Reg., Università degli Studi di Trieste, 529 p.
Presser, H. (2000): Die Orchideen Mitteleuropas und der Alpen. 2. Auf. Ecomed, Landberg/Lech, 375 p.
Ravnik, V. (1988): *Plantago argentea* Chaix in Vill. subsp. *liburnca* V. Ravnik subsp. nova. Biol. vestn., 36(3), 53–62.
Ravnik, V. (2002): Orhideje Slovenije. Tehniška založba Slovenije, Ljubljana, 192 str.
Seliškar, T., B. Vreš & A. Seliškar (2003): FloVegSi 2.0. Računalniški program za urejanje in analizo bioloških podatkov. Biološki inštitut ZRC SAZU, Ljubljana.
Skoberne, P. (2007): Narava na dlani. Zavarovane rastline Slovenije. Žepni vodnik. Mladinska knjiga, Ljubljana, 116 str.
Surina, B. (2005): Subalpinska in alpinska vegetacija Krnskega pogorja v Julijskih Alpah. Scopolia, 57, 1–122.
Škornik, S. (2003): A contribution to the knowledge of dry grassland vegetation of the *Brometalia erecti* Koch 1926 order in Slovenia. Acta Biol. Slov., 44(4), 29–43.
Škornik, S. & M. Kaligarič (2002): Relation between environmental variables, species richnes and species composition of Slovenian semi-dry meadows of *Masobromion erecti* alliance. Annales, Ser. Hist. Nat., 12(2), 141–152.
Šugar, I. (1972): Biljni svijet Samogorskog gorja. Doktorska disertacija. Sveučilište u Zagrebu, Zagreb.
Tomažič, G. (1941): Senožeti in pašniki na plitvih, pustih in suhih tleh Slovenije. Zbornik Prirodoslovnega društva, Ljubljana, 2, 67–82.
Uradni list RS 82/2002: Pravilnik o uvrstitvi ogroženih rastlinskih in živalskih vrst v rdeči seznam. Priloga 1. Rdeči seznam praprotnic in semenk (Pteridophyta & Spermatophyta). UL RS, 82/2002, Ljubljana, 24. 9. 2002.

Wraber, T. (1967): Floristika v Sloveniji v letu 1967. Biol. vestn., 15, 111–128.
Wraber, T. (1990): Sto znamenitih rastlin na Slovenskem. Prešernova družba, Ljubljana, 239 str.
Završnik, K. (2008): Steničja kukavica. Epicenter, 9(7–8), str. 19.
Zupančič, B. (1995): Klimatografija Slovenije. Padavine 1961–1990. Hidrometeorološki zavod Republike Slovenije, Ljubljana, 366 str.

DODATEK / APPENDIX

Seznam sintaksonov z njihovimi avtorji (List of syntaxa with authors):

Anemono trifoliae-Fagetum Tregubov 1962
Arrhenatheretalia R. Tüxen 1931
Arrhenatherion elatioris Koch 1926
Avenulo praeustae-Brometum erecti Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993
Brometalia erecti Koch 1926
Bromo-Brachypodietum pinnati Petkovšek 1977
Bupleuro-Brometum condensati Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993
Calluno-Ulicetea Br.-Bl. & R. Tüxen ex Klika 1948
Centaurenion dichroanthae (Pignattti 1953) Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993
Centaureo dichroanthae-Globularietum cordifoliae Pignatti 1953
Elyno-Seslerietea Br.-Bl. 1948
Erico-Pinetea I. Horvat 1959
Festucetalia valesiacae Br.-Bl. & Tüxen in Br.-Bl. 1949
Festuco-Brometea Br.-Bl. & Tüxen 1943
Hypochoeridion maculatae (Horvatić 1973) Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993
Gentianello pilosae-Brometum erecti ass. nov. hoc loco
Koelerio-Corynephoretea Klika in Klika & Novák 1941 (= *Sedo-Scleranthetea* Br.-Bl. 1955)
Lamio orvalae-Salicetum eleagni Dakskobler, Šilc & Čušin ex Dakskobler 2007
Mesobromion Zoller 1954
Molinio-Arrhenatheretea R. Tüxen 1937 em. R. Tüxen 1970
Molinion W. Koch 1926
Onobrychido arenariae-Brometum erecti Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993
Quercetalia pubescentis Klika 1933
Querco-Fagetea Br.-Bl. & Vlieg. 1937
Ranunculo bulbosi-Arrhenatheretum Ellmauer in Ellmauer & Mucina 1993
Salicetum incano-purpureae Sillinger 1933
Satureion subspicatae Horvat 1962
Saturejo variegatae-Brometum condensati Poldini et Feoli Chiapella in Feoli Chiapella et Poldini 1993
Scheuchzerio-Caricetea fuscae Tüxen 1937
Scabioso hladnikianae-Caricetum humilis (Horvat 1931) Tomažič 1941 = *Bromo-Plantaginetum mediae* Horvat (1931) 1949
Scorzonero-Chrysopogonetalia Horvatić & Horvat in Horvatić 1958 = *Scorzoneretalia villosae* Horvatić 1975
Scorzonerion villosae Horvatić 1949
Thlaspietea rotundifolii Br.-Bl. in Br.-Bl. & Jenny 1926
Trifolio-Geranietea Th. Müller 1961
Vaccinio-Piceetea Br.-Bl. 1939 emend. Zupančič (1976) 2000

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CAVES IN BRECCIA AND FLYSCH BELOW MOUNT NANOS IN THE VIPAVA VALLEY (SLOVENIA)

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ABSTRACT

Characteristic although relatively rare karst phenomena, as far as Slovenia is concerned, were discovered for this type of karst in breccia that lies on a sloping foundation of impermeable flysch. We distinguished characteristic types of caves and initial stages in the development of dolines. The largest and most frequent are caves that developed in breccia above the contact with flysch. Smaller and most often filled with fine-grained sediment are caves that occur in the middle of breccia. Of special origin are fissure caves across the slopes. Traces of continuous vertical percolation of water are less distinct. Caves are also formed in the flysch.

Key words: karstology, motorway construction, relief forms, karst caves, breccia, flysch, Slovenia

GROTTE IN BRECCIA E FLYSCH SOTTO IL MONTE NANOS NELLA VALLE DEL VIPACCO (SLOVENIA)

SINTESI

Fenomeni carsici caratteristici ma relativamente rari, almeno per quanto riguarda la Slovenia, sono stati documentati nella breccia che giace su fondamenta inclinate di flysch impermeabile. Gli autori hanno distinto tipi caratteristici di grotte e stadi iniziali di doline in sviluppo. Le più larghe e frequenti sono le grotte che si sviluppano nella breccia che si trova subito sopra al contatto con il flysch. Le più piccole e spesso colme di sedimento fine sono le grotte che si formano nel mezzo della breccia. Di origine particolare sono invece le grotte a fessura che attraversano i pendii. Tracce di continua percolazione verticale d'acqua sono meno distinguibili. Alcune grotte si sono inoltre sviluppate nel flysch.

Parole chiave: carsologia, costruzione di autostrade, forme in rilievo, grotte carsiche, breccia, flysch, Slovenia

INTRODUCTION

In the studying and planning of the Slovene motorway construction, karstologists have taken part (Kogovšek 1993, 1995; Knez *et al*. 1994, 2003, 2004, 2008; Knez & Šebela 1994; Šebela & Mihevc 1995; Mihevc 1996, 1999; Mihevc & Zupan Hajna 1996; Slabe 1996, 1997a, 1997b, 1998; Kogovšek *et al*. 1997; Mihevc *et al*.1998; Šebela *et al*.1999; Bosak *et al*. 2000; Knez & Slabe 2000, 2001, 2002, 2004a, 2004b, 2005, 2006, 2007). A large part of the motorway system runs across karst areas. Our mission is to identify and describe the newly discovered natural heritage, and our knowledge, especially about the caves in the karst, is frequently of technical help to road builders.

The Vipava Valley lies between the high karst plateaus of Trnovski gozd and Mount Nanos to the north and the low plateau of the Classical Karst to the south. Mount Nanos is overthrust on flysch. Below its steep western edge on the sloping flysch, scree material accumulated and consolidated into breccia that developed into a special young karst (Fig. 1).

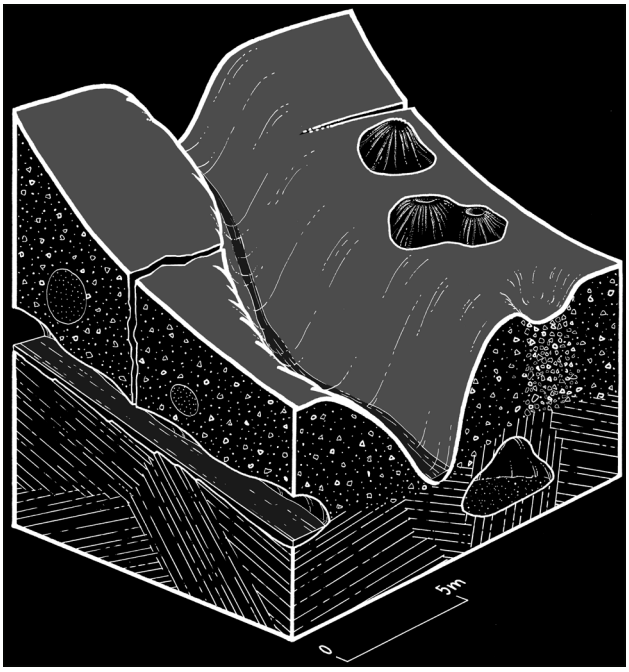

Fig. 1: Karst in breccia and flysch below Mount Nanos in the Vipava Valley: surface karren, with small doline and washed belt of breccia below it and caves in breccia, at the contact of breccia and flysch, and in flysch.
Sl. 1: Zakraselost breče in fliša na pobočjih Nanosa v Vipavski dolini: s škrapljami na površju, z manjšo vrtačo in s pasom izprane kamnine pod njo ter jamami v breči, na stiku breče in fliša in v flišu.

During the thorough and long-term motorway construction monitoring, characteristic although for Slovenia relatively rare karst phenomena were discovered in breccia that lie on a sloping foundation of impermeable flysch. We distinguished characteristic types of caves and early stages in the development of dolines.

GEOMORPHOLOGICAL DEVELOPMENT OF THE SITE AND GEOLOGICAL CONDITIONS

Geomorphology

The motorway alignment runs across three geomorphologically diverse units along the southwestern slopes of Mount Nanos (Rebrnice and Breg) and the floor of the Vipava Valley (Fig. 2). The Breg and Rebrnice slopes are distinct geomorphological units. Mihevc (2001) geomorphologically mapped the slopes of Mount Nanos in detail over part of the motorway alignment that runs through the landscape park area. A specific geological thrust structure and specific slope processes and sediments are reflected here in the morphology of the slopes and in botanical anomalies. These features have led to the proclamation of a landscape park covering the southern and western slopes of Mount Nanos.

The surface of the slopes was formed by the mass movement and mechanical weathering of rock, which was accompanied on the flysch bedrock by landslides. Water that flowed above the flysch also dissected the slopes (Fig. 3). The thickness of the layers of scree material or breccia varies from place to place. More or less vertical fissures developed in the breccia that indicate tensions in the slopes. During the motorway construction, the contact between scree material and breccia and the flysch bedrock showed an extremely fragile balance where the alignment cuts deeply into the slope. After abundant precipitation, numerous smaller streams appeared along the contact between flysch and breccias revealed by the cuts. Many of these streams are exploited for water supply.

Water percolates from the surface in a more or less evenly dispersed fashion through mostly well permeable breccia to the contact with flysch. However, in individual places, traces of continuous percolation of water can be clearly seen in the cross section of breccia and scree material. These are one- to two-meter wide belts of washed scree and breccia, the beginnings of dolines (Fig. 4). Above them, small sinkholes formed whose diameters do not exceed three meters. They are covered with soil. The water from the surface also carries soil containing organic material that further accelerates the dissolving of carbonate rock.

Rainwater has carved rock relief forms on the larger rocks that protrude from the karst surface, the most distinct being flutes and solution pans. Mature flutes take

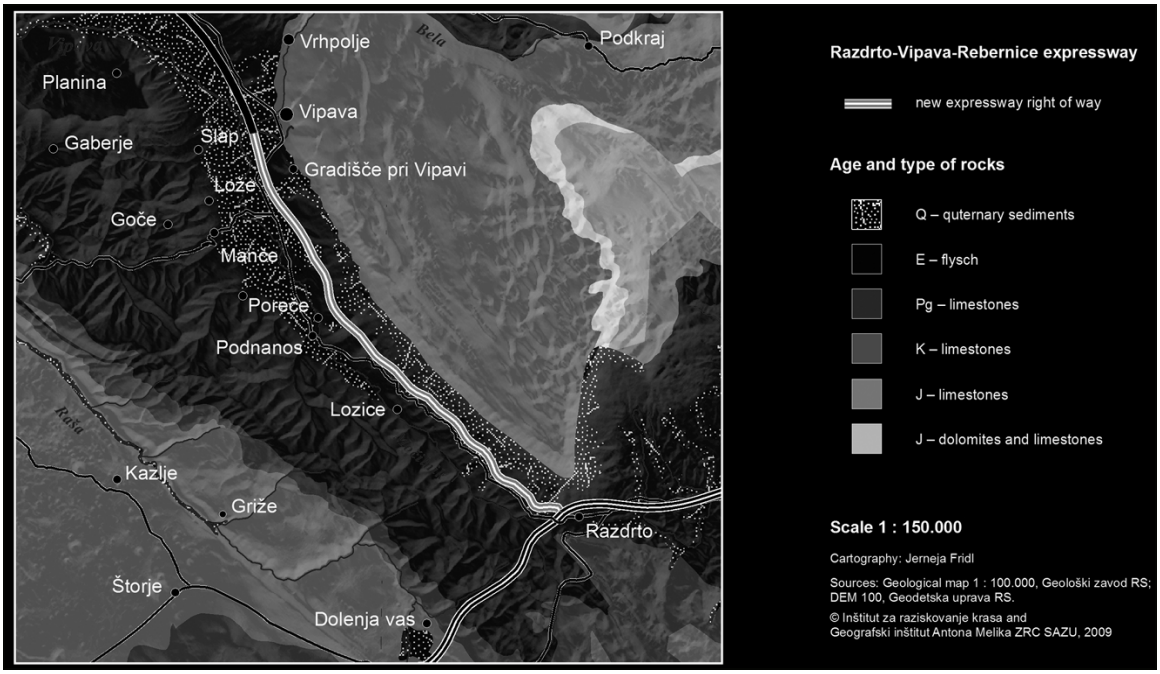

Fig. 2: Motorway alignment along the slopes of Mount Nanos.
Sl. 2: Potek avtoceste po pobočju Nanosa.

Fig. 3: Valley cut in breccia above impermeable flysch.
Sl. 3: Dolina, vrezana v breči nad neprepustnim flišem.

two thousand years to develop (Gams, 1990). Therefore, the surface of mass movements and landslides on parts of the slopes has not changed significantly for a long time.

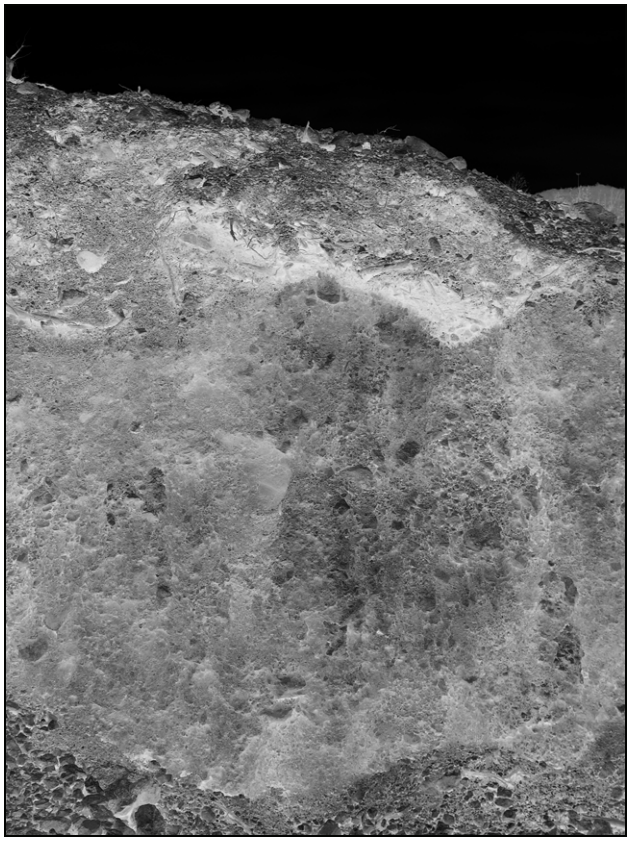

Fig. 4: Early stage of doline development.
Sl. 4: Začetno obdobje razvoja vrtače.

Geology

Geologists first studied the slopes of Mount Nanos and the Trnovski gozd range during the geological mapping of the area. On the slopes they established, in detail, the contact between flysch and limestone and the distribution of the Quaternary cover of scree material and larger mass movements (Buser *et al.*, 1967; Mlakar, 1969; Placer 1981). They also studied the contact between limestone and flysch on the eastern side of Mount Nanos along the edge of the Pivka basin (Čar, 1980). Jež (2007) described slides of scree material and breccia. The younger talus that formed below the wall pushed older scree material and breccia that slid downward. Melik (1960) described distinctive slopes in his monograph, while Habič (1968) studied the slopes of Mount Nanos in his examination of the Nanos and Trnovski gozd high karst plateaus. He described various slope materials, scree material, conglomerate, remains of mass movements, and larger talus and fans. In the Rebrnice area, he observed inverse relief where thicker layers of scree material and breccia in former ravines carved into the flysch bedrock. Around Črniče Radinja (1961), observed various slope sediments and sliding of slope scree material on flysch and attempted to determine individual genetic types of gravel.

Limestone outcrops in the vicinity of the motorway alignment in only a few places. In the Mlake area at the military firing range, limestone composed of nummulitic breccia has built a smaller elevation between flysch layers. Several smaller areas in the slopes are composed of Cretaceous rudistid limestone, for example at Šembijski zatrep above Podnanos and the smaller patch of Cretaceous limestone near Orešje and Lozice.

Breccia

In the cross sections of the slope exposed by cuts for the motorway, it is frequently possible to observe many layers of scree material and breccia (Fig. 5). Their total thickness often exceeds ten meters, and in individual places exposed during the digging of foundations for the viaduct pillars even reached twenty-five meters. As a rule, the layers differed relative to the degree of cementation of the breccia. Only individual layers were relatively well cemented. The carbonate cement connected scree material in breccia first and most firmly around larger rocks. The excavation work frequently revealed chunks of breccia several cubic meters in size, surrounded by uncemented or poorly cemented scree material. Between the larger and smaller pieces of scree material and rock forming the breccia were hollow spaces partly filled with flowstone. The degree of cementation of breccia is therefore the consequence of the age of the mass movements, a deep or shallow position below the surface, the sliding and breaking of older breccia, and the characteristics of the water that percolated regularly from the surface, which is covered by a thin layer of soil and vegetation. Of course, in individual places the breccia is already uniquely karstified.

The water that percolates through the scree material and breccias carries dissolved calcium carbonate. The cement between clasts of breccia is almost exclusively carbonate in nature. Pieces in the breccia are fragments of Senonian, Turonian, and Cenomanian limestone and most probably of Lower Cretaceous limestone as well. The Lower Cretaceous layers in the upper half of the Mount Nanos slopes developed similarly to the Upper Cretaceous Cenomanian limestone (Pleničar, 1970; Buser, 1973) and therefore are not shown separately on the maps (Buser *et al.*, 1967; Buser 1968).

The porosity of breccia varies according to the composition of the material forming it and the local percolation. The spaces between clasts do not contain any fine material and the clasts are not covered with flowstone. A similar structure is observed in seemingly similar breccias, except that their clasts are completely covered with a millimetre or two of layered, mostly porous or white flowstone. There is also no fine material between them. This type of breccia is very porous. Only partially porous breccias were formed where the water between the clasts brought weathered debris and fewer fine limestone clasts from the surface. In places where fine limestone fragments the size of sand accumulated between clasts that are several centimetres in diameter, breccia is substantially less porous. It also contains weathered debris cemented in flowstone. In some cases, calcium carbonate in which water deposited major quantities of weathered debris served as a cementing agent to bind the clasts. Even in this case, the breccia is poorly or almost non-porous, and the cement is of characteristic

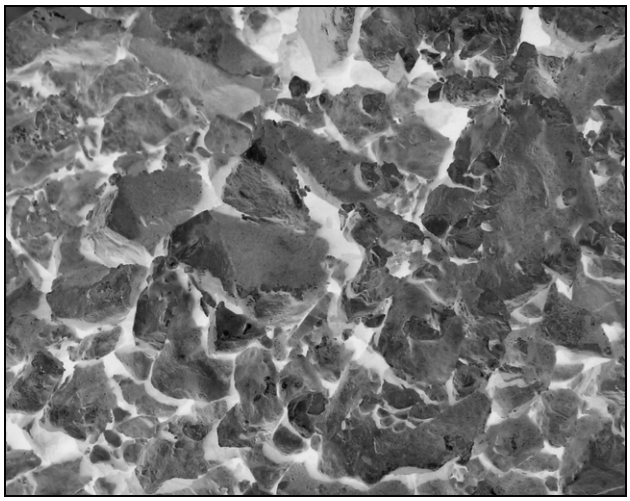

Fig. 5: An example of porous breccia. Width of picture is 25 cm.
Sl. 5: Primer porozne breče. Širina slike je 25 cm.

Fig. 6: Contact between scree material and flysch. Width of picture is 4 m.
Sl. 6: Stik grušča in fliša. Širina slike je 4 m.

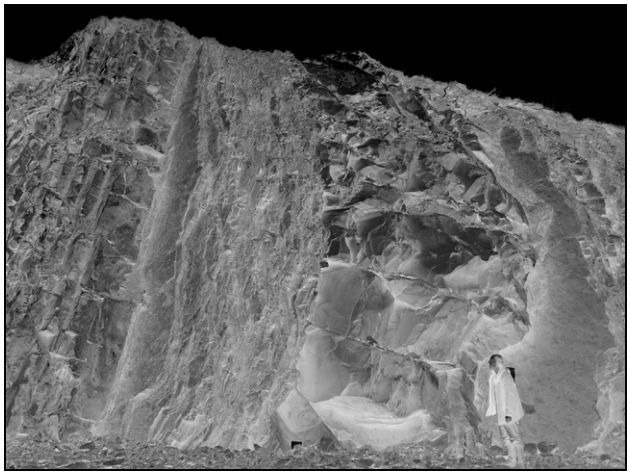

Fig. 7: Layers of flysch.
Sl. 7: Plasti fliša.

red-brown colour. In places, cavities were formed between the clasts, where the beginnings of larger calcite crystals can be observed.

Flowstone often fills the smaller spaces between the rock fragments that compose breccia. Where there is room, straws form on the ceiling of cavities. When parts of the breccia are composed of rocks, smaller flowstone domes are formed whose stratification indicates, in places, the originally filled cavity. A ribbed flowstone coating occurs on the walls of slope fissures. Larger domes of flowstone were naturally discovered in caves originating along the contact with flysch.

Flysch

Flysch layers lie beneath the breccia (Fig. 6). On the south side of Mount Nanos, in the area near Razdrto and in the Rebrnice slope, the flysch layers dip generally toward the southeast. Near Podboršt, northwest of Podnanos, where they dip in the same direction, they slant much more steeply. Farther to the northwest near Vipava, the layers of limestone and flysch are almost vertical (Fig. 7).

In the flysch rocks, the dominant grey to black shale marlstone and massive marlstone alternate with carbonate and quartziferous sandstone. The latter contains a significant amount of carbonate particles and carbonate cement. Occasionally, the almost black marlstone laterally transforms into brown ochre. In most cases, it has a characteristic conchoidal fracture.

In places, we observed that the marlstone layers alternated with thicker layers of dark grey calcarenite, siltstone, and claystone. The clastic rocks have a very steep dip, lying between 70º and 80º relative to the slope, and the general direction of the dip is toward the north or northeast. In places, the layers are subvertical.

The lithological contact between Cretaceous limestone and Eocene flysch runs mainly high up on the slopes of Mount Nanos, mostly around two hundred meters above the motorway alignment. The contact is morphologically distinct, since the slopes are steep or even vertical on limestone and more gently sloping on flysch rock.

CAVES IN BRECCIA AND FLYSCH

Many characteristic types of caves were formed in the breccia that developed on steep and dissected flysch slopes. The largest and most frequent are caves (20) that developed in the breccia above the contact with flysch, while caves (10) that occur in the middle of the breccia are smaller and most often filled with fine-grained sedi-

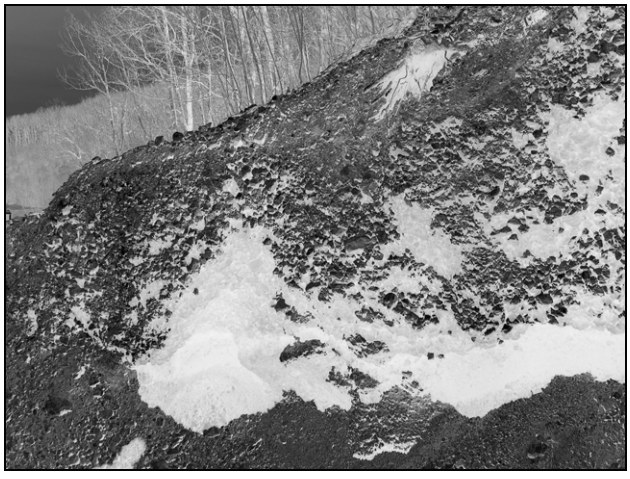

Fig. 8: Cave in breccia at the contact with flysch.
Sl. 8: Jama na stiku breče in fliša.

ment. Fissure caves (10) that cross the slopes are of special origin. Traces of continuous vertical percolation of water are less distinct. Caves (5) also occur in the flysch.

Remškar (2006) collected data on caves in breccia in the Vipava Valley, specifying types of caves and their origin. He divided them into those that developed along fissures, those formed by streams of water, and rock shelters.

Caves at the contact of breccia and flysch

These are the most frequently discovered caves in this young karst. The diameter of smaller tubes measures only a decimetre, while the height of the largest tubes can reach two meters and their width three meters (Fig. 8). The largest parts of the passages are cupola-shaped widenings. These are narrower and higher along fissures. The size and shape of their cross sections vary distinctly from meter to meter along the length of the passage. In places, the shape of the cave reflects the different stages of breccia cementation. The more consolidated the breccia, the smaller the cross sections of passages in the same condition. The composition of the rock also dictates the fine dissection of the circumference of the passages. The floors of caves, through which water flows, are flysch that is only partly covered with pieces of scree material, while the floors of dry caves are covered by scree material and domes of flowstone, since breccia tends to disintegrate. There are smaller stalactites on the longer enduring part of the circumference. The thicker layers of flowstone found at various heights in the cave bear witness to times when the caves were filled with fine-grained sediment.

In most cases, individual passages were opened and their connection to a branched network was revealed in only a few places. The largest cave revealed was fifteen meters long. Its central part, a dome-shaped dissected passage was found (Fig. 9). The diameter of the largest dome measured three meters. On the floor, which was largely covered with scree material, a larger stalagmite had formed. We did not observe any traces of water, but a small quantity of water could have percolated through the scree material covering the cave floor.

The part of the cave with a permanent stream preserved during the excavation work was ten meters in length. It was three meters wide and one and a half meters high, and a small stream flowed through it.

Individual caves are filled with fine-grained flysch sediment. Water flowing along the contact carves the flysch bedrock and fills poorly permeable parts of the caves. It appears that some of the caves were formed while they were in the process of filling with sediment that is preserved in places and was elsewhere washed away due to the increased conductivity of the caves. Traces of earlier fillings are found in the flowstone crusts preserved at different heights in the cross sections of the passages. The lower parts of larger caves are carved deeper into the flysch rock.

Often, only smaller continuous streams that have not yet formed distinctive caves are evident in the cross sections of the slopes. After abundant precipitation, they

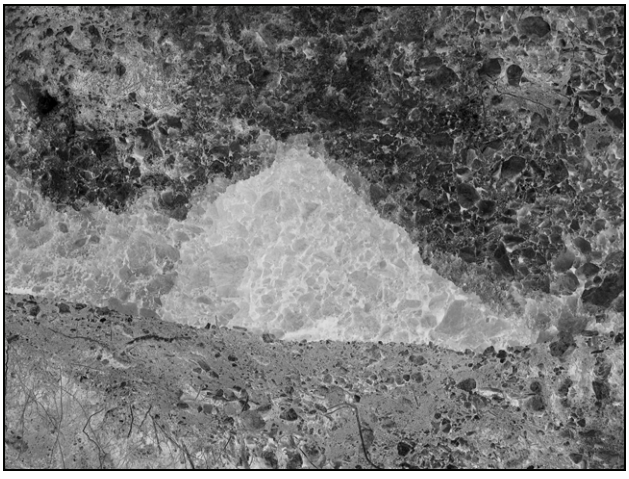

Fig. 9: Cupola-shaped widenings of cave passage. Width of picture is 3 m.
Sl. 9: Kupolasta razširitev rova. Širina slike je 3 m.

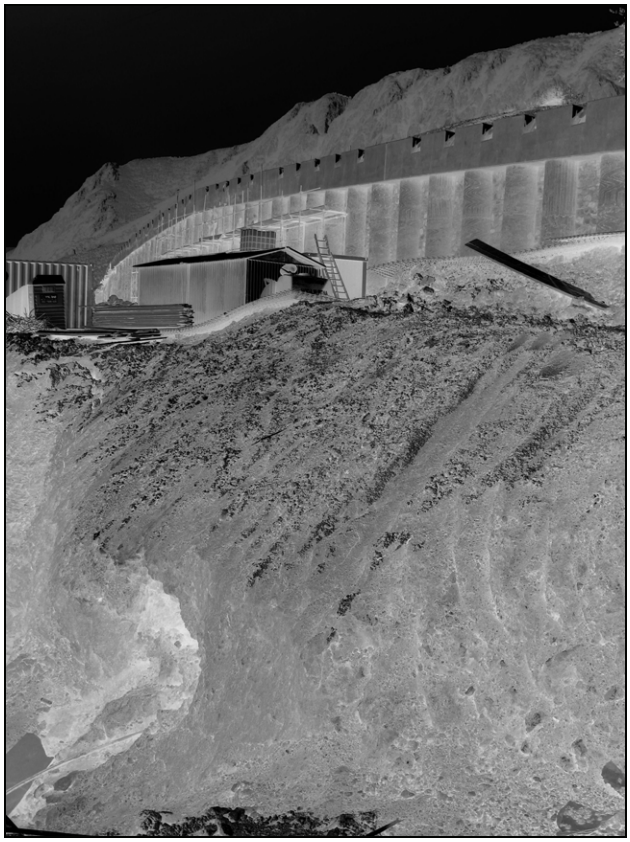

Fig. 10: Contact cave with water flow.
Sl. 10: Jama z vodnim tokom na stiku breče in fliša.

flow side by side. This is the consequence of high porosity of breccia and its contact with flysch. In most cases, the flysch proves to be a poorly permeable rock, especially its upper layer, which is weathered and clayey.

The passages of the revealed caves run down the slope. They occurred due to the flowing of water at the contact of breccia and the flysch covered by breccia (Fig. 10). The water permeating through the scree material and breccia congregates on the sloping flysch. Conditions for the formation of caves occur along larger continuous streams. Breccia was carried away in a number of places, and smaller valleys formed alongside the streams.

Sediment-filled caves

The diameters of these caves do not exceed one meter, and as a rule they are smaller (Fig. 11). The cross sections of the caves are more or less circular or elliptical in shape, as they were usually formed along the contacts between layers of different types of breccia and along fissures. They are found in all the cross sections of breccias, but primarily in the most consolidated and least porous parts of breccia. As a rule, they are filled with brown sediment and soil washed from the surface by water.

The contact between the flysch at the bottom and the breccia above is not flat but distinctly undulating and finely dissected. This is the consequence of the diverse geological structure of flysch, its variously lying layers, and the erosive action of water that has flowed and continues to flow either on the contact with breccia or in smaller valleys on the flysch. Even though there is very porous karst on a slope, less permeable sections, sometimes even flooded zones, are formed locally and occasionally in places where caves were formed in the breccia. Sediments, mainly soil washed from the surface, are deposited in them, and the caves widen along the sediments. In one of the wells used as a foundation for a bridge, water began to appear in the breccia several meters above the contact with flysch.

Fissure caves

Fissure caves are formed along fissures that developed in breccia (Fig. 12). As a rule, they cross the slopes. The largest caves, which are several meters or even several dozen meters long and in places up to one meter wide are accessible. Most of them, however, are narrower and do not exceed one decimetre in width. The depth of such caves is conditioned by the thickness of the breccia layers and the characteristics of the fissure. They are shaped by the water percolating in them. Some of these caves are filled with fine-grained sediments and soil where the rock dissolves more rapidly, and the walls of other caves are coated with flowstone. The smallest caves can be completely filled with flowstone.

Fig. 11: Cave filled with sediment.
Sl. 11: Jama, zapolnjena z naplavino.

Fig. 12: Fissure caves.
Sl. 12: Špranjaste votline.

Caves in flysch

In addition to caves that opened at the contact of breccia and flysch, we also encountered caves that formed within the framework of flysch rock at the contact of marlstone and quartziferous sandstone and of carbonate sandstone and calcarenite.

In some places, we observed significant water flow at the contact of carbonate and non-carbonate rock. The contact with non-carbonate rock is not only a water barrier but also an area where water can stagnate and where its level can fluctuate. This causes the material being washed and carried away, changes in pressure can occur here, and the water can form larger channels. Both limestone and flysch particles are transported along these paths.

In addition, we determined in many places that a small number of underground conducting channels had formed in flysch rock. In places where flysch layers are fractured or folded, water flows along the fissures or spaces between the layers. There is a flow of water along the interbedded contacts due to the almost vertical layers. Water flowing along these contacts carries away the flysch material, widens the fissures, and simultaneously periodically or laterally deposits calcium carbonate in different ways. We can frequently observe calcite fillings of fissures that are several centimetres thick. In places, the fissures are completely filled, elsewhere up to one centimetre large scalenoedric calcite crystals were formed in the fissures, and a number of fissures are covered by a thin (a few millimetres) coat of flowstone. In marlstone with distinctly conchoidal fractures, a number of fissures have been filled with coarse-crystal calcite. It is important to emphasize that the cement is carbonate and that a number of layers can contain much more than 10% of particles of carbonate origin. Therefore, both erosion and corrosion occur when water flows through the fissures and along the faults. There is no doubt that karstification takes place to a very small extent.

Fig. 13: Entrance to flysch cave.
Sl. 13: Vhod v jamo v flišu.

Heavy weathering of the rock in the interior of the tectonically undeformed block of rock occurs along fissures and faults where the precipitation and surface water flow. Calcium carbonate (flowstone) is deposited at the majority of such contacts.

Caves were formed at the contact of marlstone and calcarenite (Fig. 13). One of the more characteristic caves of this type, measuring up to five meters in depth and width, opened to the north of the Tabor tunnel at the northwestern part of the alignment. Here are layers of dark grey to black marlstone from a few dozen centimetres to half a meter thick that due to their solidity have a clearly visible conchoidal fracture. The calcarenite is heavily fractured, so that numerous calcite veins further increase the content of carbonate. Because the layers have a dip between 70º and 90º, the water passes easily between the layers. Although the calcarenite layers are being intensely dissolved by rainwater, larger cavities or even caves are not formed due to the fractured rock.

CONCLUSIONS

The geological, geomorphological, speleological, and hydrological diversity of Slovenia's karst has been demonstrated also by the study of the karstification of breccia that formed beneath the western slopes of Mount Nanos. Water, in most cases percolating diffusely through the permeable surface of scree material or breccia to the more or less impermeable flysch bedrock, creates young karst phenomena.

Rainwater covers large rocks on the karst surface with flutes and solution pans. Fissures crossing the rock in the direction of the slope indicate tensions in the rock mass and its exposure to sliding. Breccia and scree material lie on slanting flysch, and most of the water flows along the contact causing their instability.

The percolating water is collected where the breccia is most consolidated. Earthworks have revealed the early stages in the formation of unique dolines.

Characteristic types of caves developed in the young and very porous breccia, which is consolidated only in places, lying on the more or less slanting flysch, an impermeable bedrock. The true karst caves are small and their development was influenced by the sediment that as a rule fills them. They were formed in a locally and periodically flooded zone and are often paragenetically enlarged. The largest caves were formed above the contact with the impermeable flysch bedrock, where the largest streams join. Their shape reflects the varying degrees of consolidation of the breccia. In areas where the breccia is less solid and along fissures, they rise into domes. Along the fissures that are the consequence of

the breccia and scree material sliding down the slanting bedrock of frequently saturated flysch, fissure caves were formed across the slope; some of them are very long and wide enough in places to make them accessible. As a rule, their walls are covered with flowstone.

To a very small extent, karstification also takes place inside the flysch where the marlstone or sandstone contains at least calcite cement. Karstification at the contacts of marlstone and calcarenite, where caves several meters in size are formed, is more significant. In places with almost vertical layers, water quickly percolates into the underground, but the heavily fractured layers hinder the formation of larger caves.

Although the described karst is relatively young, discovered in its early development stages, it still reveals all the characteristics of the karstification of breccia in characteristic geological, geomorphological, and hydrological conditions. Learning about it expands our knowledge of Slovenia's diverse natural karst heritage and forms the basis for future planning of various spatial interventions in the environment.

ACKNOWLEDGEMENTS

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JAME V BREČI IN FLIŠU POD NANOSOM V VIPAVSKI DOLINI (SLOVENIJA)

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POVZETEK

Površje pobočja jugozahodnega dela Nanosa so oblikovali podori in mehansko razpadajoča kamnina. Pobočje so razčlenile tudi vode, ki se pretakajo nad flišem. V breči so nastale bolj ali manj navpične razpoke, ki kažejo na napetosti v pobočju. Med graditvijo avtoceste, ko se je trasa globlje zasekala v pobočje, pa je stik med gruščem, brečo in flišno podlago pokazal izredno krhko ravnotežje. Po obilnih padavinah je po stiku med flišem in brečo, ki so ga razkrili useki, na dan privrela množica manjših vodnih tokov.

Zemeljska dela med graditvijo avtoceste na odseku med Razdrtim in Vipavo so razkrila za tovrstni kras v brečah, ki leže na nagnjeni neprepustni osnovi fliša, značilne in pri nas razmeroma redke kraške pojave. Razločili smo značilne vrste jam in začetne stopnje razvoja vrtač. Največje in najbolj pogoste so jame, ki so nastale v breči nad stikom s flišem, manjše in največkrat z drobnozrnato naplavino zapolnjene so jame, ki so sredi breče, posebnega izvora pa so razpoklinske jame, prečne na padec pobočja. Sledi strnjenega navpičnega prenikanja vode so manj izrazite. Jame nastajajo tudi v flišu.

Ključne besede: krasoslovje, graditev avtocest, reliefne oblike, kraške jame, breča, fliš, Slovenija

REFERENCES

Bosak, P., M. Knez, D. Otrubova, P. Pruner, T. Slabe & D. Venhodova (2000): Paleomagnetic Research of Fossil Cave in the Highway Construction at Kozina (SW Slovenia). Acta carsologica, 29(2), 15–33.

Buser, S. (1968): Osnovna geološka karta SFRJ Gorica 1:100.000. Zvezni geološki zavod, Beograd.

Buser, S. (1973): Tolmač lista Gorica. Osnovna geološka karta SFRJ 1:100.000. Zvezni geološki zavod, Beograd.

Buser, S., K. Grad & M. Pleničar (1967): Osnovna geološka karta SFRJ Postojna 1:100.000. Zvezni geološki zavod Beograd.

Čar, J. (1980): Šmihelska tektonska krpa. Geologija, 23(2), 279–283.

Gams, I. (1990): Depth of Rillenkarren as a mesure of deforestation age. Studia carsologica, 2, 29–36.

Habič, P. (1968): Kraški svet med Idrijco in Vipavo. Dela SAZU, 243 str.

Jež, J. (2007): Vzroki in mehanizem zemeljskega plazenja na Rebrnicah v Vipavski dolini. Geologija, 50(1), 55–63.

Knez, M. & T. Slabe (2000): Jame brez stropa so pomembna oblika na kraškem površju: s krasoslovnega nadzora gradnje avtocest na krasu. V: Gostinčar, A. (ur.): 5. slovenski kongres o cestah in prometu. Zbornik pov-

zetkov referatov. Družba za raziskave v cestni in prometni stroki Slovenije, str. 29.
Knez, M. & T. Slabe (2001): Karstology and expressway construction. Proc. 14th IRF Road World Congress, Paris.
Knez, M. & T. Slabe (2002): Unroofed caves are an important feature of karst surfaces: examples from the classical karst. Z. Geomorphol., 46(2), 181–191.
Knez, M. & T. Slabe (2004a): Karstology and the opening of caves during motorway construction in the karst region of Slovenia. Int. J. Speleol., 31(1/4), 159–168.
Knez, M. & T. Slabe (2004b): Highways on karst. In: Gunn, J. (ed.): Encyclopaedia of caves and karst science. Fitzroy Dearborn, New York, London, pp. 419–420.
Knez, M. & T. Slabe (2005): Caves and sinkholes in motorway construction, Slovenia. In: Waltham, T., F. Bell & M. Culshaw (eds.): Sinkholes and Subsidence. Karst and Cavernous Rocks in Engineering and Construction. Springer, Chichester, pp. 283–288.
Knez, M. & T. Slabe (2006): Dolenjska subsoil stone forests and other karst phenomena discovered during the construction of the Hrastje – Lešnica motorway section (Slovenia). Acta carsologica, 35(2), 103–109.
Knez, M. & T. Slabe (ur.) (2007): Kraški pojavi, razkriti med gradnjo slovenskih avtocest. Založba ZRC, Ljubljana, Carsologica št. 7, 250 str.
Knez, M. & S. Šebela (1994): Novo odkriti kraški pojavi na trasi avtomobilske ceste pri Divači. Naše jame, 36, 102.
Knez, M., A. Kranjc, B. Otoničar, T. Slabe & S. Svetličič (1994): Posledice izlitja nafte pri Kozini. Ujma, 9, 74–80.
Knez, M., B. Otoničar & T. Slabe (2003): Subcutaneous stone forest (Trebnje, Central Slovenia). Acta carsologica, 32(1), 29–38.
Knez, M. & T. Slabe & S. Šebela (2004): Karstification of the aquifer discovered during the construction of the expressway between Klanec and Črni Kal, Classical Karst. Acta carsologica, 33(1), 205–217.
Knez, M. & T. Slabe, S. Šebela, & F. Gabrovšek (2008): The largest karst caves discovered in a tunnel during motorway construction in Slovenia's Classical Karst (Kras). Environ. Geol., 54(4), 711–718.
Kogovšek, J. (1993): Water composition flowing off our roads. Ujma, 7, 67–69.
Kogovšek, J. (1995): Datailed monitoring of the quality of the water that runs off the motorway and its impact on karst water. Annales, Ser. Hist. Nat., 5(1), 149–154.
Kogovšek, J., T. Slabe & S. Šebela (1997): Motorways in Karst (Slovenia). Proceedings & Fieldtrip excursion guide. 48th Highway Geology Symposium, pp. 49–55.
Melik, A. (1960): Slovenija 2. Slovensko primorje. Slovenska matica, Ljubljana, 546 str.
Mihevc, A. (1996): The cave Brezstropa jama near Povir. Naše jame, 38, 65–75.
Mihevc, A. (1999): Etudes de géographie physique, suppl. XXVIII, Colloque européen-Karst 99, pp. 141–144.
Mihevc A. (2001): Geomorfološko kartiranje na delu trase HC Razdrto–Vipava (Rebernice), ki poteka v območju krajinskega parka. IZRK ZRC SAZU, Postojna, 49 str.
Mihevc, A. & N. Zupan Hajna (1996): Clastic sediments from dolines and caves found during the construction of the motorway near Divača, on the Classical Karst. Acta carsologica, 25, 169–191.
Mihevc, A., T. Slabe & S. Šebela (1998): Denuded caves. Acta carsologica, 27(1), 165–174.
Mlakar, I. (1969): Krovna zgradba idrijsko žirovskega ozemlja. Geologija, 12, 5–72.
Placer, L. (1981): Geološka zgradba jugozahodne Slovenije. Geologija, 24(1), 27–60.
Pleničar, M. (1970): Tolmač lista Postojna. Osnovna geološka karta SFRJ 1:100.000. Zvezni geološki zavod, Beograd, 62 str.
Radinja, D. (1961): Neka iskustva u proučevanju gruboklastičnog materiala sa morfometrijskom metodom. Zbornik radova. 6. kongr. geogr. Jug., str. 235–243.
Remškar, B. (2006): Jame v breči na južnem pobočju Trnovskega gozda. Naše jame, 46, 4–15.
Slabe, T. (1996): Karst features in the motorway section between Čebulovica and Dane. Acta carsologica, 13, 221–240.
Slabe, T. (1997a): Karst features discovered during motorway construction in Slovenia. Environ. Geol., 32(3), 186–190.
Slabe, T. (1997b): The caves in the motorway Dane-Fernetiči. Acta carsologica, 26(2), 361–372.
Slabe, T. (1998): Karst features discovered during motorway construction between Divača and Kozina. Acta carsologica, 27(2), 105–113.
Šebela, S. & A. Mihevc (1995): The problems of construction on karst – the examples from Slovenia. In: Beck, B. F. & F. M. Pearson (eds.): Karst geohazards – Engineering and environmental problems in karst terrane. Proc. 5th Multidisciplinary Conference on Sinkholes and the Environmental Impacts of Karst. A. A. Balkema, Rotterdam, pp. 475–479.
Šebela, S., A. Mihevc & T. Slabe (1999): The vulnerability map of karst along highways in Slovenia. In: B. F. Beck, A. J. Pettit & J. G. Herring (Eds.): Hydrogeology and engineering geology of sinkholes and karst. Proc. 7th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst. A. A. Balkema, Rotterdam, pp. 419–422.

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CHEMICAL CHARACTERIZATION OF STROMATOLITIC "PETOLA" LAYER (SEČOVLJE SALT-PANS, SLOVENIA) USING FT-IR SPECTROSCOPY

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ABSTRACT

At Sečovlje salt-pans (Gulf of Trieste, northern Adriatic), the stromatolitic microbial mat named "petola" is a crucial element in old mediaeval manner of salt-production, so the understanding of its chemistry is highly significant for the preservation and progress of this activity. The infrared spectra (FT-IR) of homogenized bulk samples were recorded to investigate the petola composition and modifications. The FT-IR results revealed carbonates, gypsum ($CaSO_4 \cdot 2H_2O$) and silicates as the major inorganic components, while the content of organic matter (OC; 4.3–6.4 wt. %) was rather low. During sampling period, including increase of brine salinity and maturation of petola, the concentration of silicates, organic carbon (OC) and total nitrogen (TN) is greatly reduced and the carbon nitrogen (OC/TN) atomic ratio increased. The present work confirmed the usefulness of FT-IR techniques for characterization of petola composition and its transformation and suggests its application for fundamental investigations of hypersaline systems.

Key words: stromatolite-petola, FT-IR, elemental composition, Sečovlje salt-pans, northern Adriatic Sea

CARATTERIZZAZIONE CHIMICA DELLO STRATO STROMATOLITICO "PETOLA" (SALINE DI SICCIOLE, SLOVENIA) CON L'USO DELLA SPETTROSCOPIA FT-IR

SINTESI

Alle saline di Sicciole (Golfo di Trieste, Adriatico settentrionale), lo strato stromatolitico microbico chiamato "petola" è un elemento cruciale nella produzione del sale col vecchio metodo medievale, quindi la conoscenza del suo processo chimico è molto importante per la conservazione e lo sviluppo di tale attività. Allo scopo di ricercare la composizione e le modificazioni della petola è stato registrato lo spettro infrarosso (FT-IR) di grandi campioni omogeneizzati. I risultati FT-IR hanno rivelato la presenza di carbonati, gesso ($CaSO_4 \cdot 2H_2O$) e silicati quali componenti inorganici principali, mentre è risultato basso il contenuto in materia organica (OC; 4,3–6,4 wt. %). Durante il periodo di campionamento, compreso l'incremento della salinità dell'acqua salmastra e la maturazione della petola, la concentrazione di silicati, carbonio organico (OC) e azoto totale (TN) si è di molto ridotta, mentre è aumentato il rapporto atomico carbonio azoto (OC/TN). La ricerca conferma l'utilità delle tecniche FT-IR per la caratterizzazione della composizione della petola e della sua trasformazione e suggerisce l'applicazione di tali tecniche per l'indagine fondamentale dei sistemi ipersalini.

Parole chiave: stromatoliti-petola, FT-IR, composizione elementare, saline di Sicciole, Adriatico settentrionale

INTRODUCTION

In the past, the littoral region along the Gulf of Trieste was greatly marked by salt-pans that are now mainly abandoned. Nowadays, the Sečovlje and Strunjan salt-pans are the only ones on our coast where salt production has survived. Sečovlje salt-pans are also known for their characteristic landscape and as an area with rich natural and cultural heritage. In 1993, they were included on the list of wetlands of international concern, as stipulated by the Ramsar Convention, and are one of the most important tourist and educational destinations. Today, the protection and preservation of natural and cultural heritage within Sečovlje Salina Nature Park and production of salt in the traditional manner are under the auspices of SOLINE Pridelava soli d.o.o. (Salt Production Co. Ltd.).

The Sečovlje solar (Fig. 1) salt-pans are located in the southern part of Piran Bay (northern Adriatic) along the River Dragonja delta. Salt production proceeds by fractional salt precipitation and finally the selective recovery of a very pure NaCl through solar evaporation and concentration of seawater in crystallization basins. Due to different solubility, the evaporation process from supersaturated seawater initially results in precipitation of $CaCO_3$, followed by crystallization of $CaSO_4$, and finally the halite precipitates (Faganeli *et al.,* 1999). The salt is produced on "petola", *i.e.* microbial (stromatolitic) mat dominated by cyanobacteria and cemented with gypsum, calcite and clay (Faganeli *et al.*, 1999). This a few millimetres thick layer of biosediment forms the bottom of a crystallizing salt basin and enables the traditional gathering of salt. The algal mat stabilizes sediment surface (Schneider & Herrmann, 1980) and of just right thickness and undamaged provide for enough solidity and elasticity for manual gathering of salt on the petola. At the beginning of cultivation, the petola constitutes a liable substrate that at the end of this process becomes solid and plastic. The petola also prevents the mixing of muddy floor with seawater and salt, contributing to the production of very pure, white and tasteful unrefined sea salt. For this reason, the salt-workers cultivate and maintain this basin's base throughout the year with great care. However, there is a lack of studies as far as solid (sediment) and aqueous (brine) phases of salt-pans are concerned. In the last 15 years, very few studies concerning sedimentological and biogeochemical properties of this hypersaline environment have been carried out (Dolenec *et al.*, 1994; Faganeli *et al.*, 1999; Ogorelec *et al.*, 2000). As no studies of seasonal transformations of the petola have been performed as yet and as FT-IR has been recognized as a powerful tool for chemical characterization and degradation processes of natural samples, the purpose of this study was chemical characterization and petola modification (affected by maturation processes) using FT-IR spectroscopy. In this way we also checked the applicability of spectroscopic techniques to study the diagenetic processes in this hypersaline environment.

MATERIALS AND METHODS

Sampling site and samples

Sediment samples were taken from crystallization basin in the solar salt-pans of Sečovlje, located in the Bay of Piran (northern Adriatic, Slovenia) (Fig. 1), on June 8th (Sample A), June 30th (Sample B), and July 3th (Sample C), in 2006.

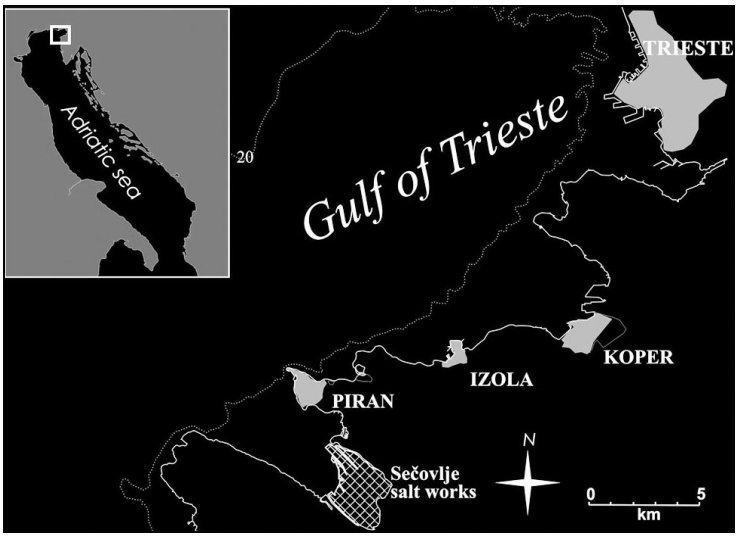

Fig. 1: Location of the Sečovlje salt-pans sampling site (Gulf of Trieste, northern Adriatic).
Sl. 1: Vzorčevalno mesto – Sečovljske soline (Tržaški zaliv, severni Jadran).

Surface sediment samples (0–2 cm) were collected using 40 mm diameter gravity core sampler (Meischner & Rumohr, 1974) and then the tiny slice of surface sediment, *i.e.* 2–3 millimetre thick layer of biosediment, was cut off and frozen. The freeze-dried samples were grounded to a fine powder and used for elemental and FT-IR analyses.

FT-IR spectra were obtained on homogenized samples using a Perkin-Elmer Spectrum One spectrometer with diffuse reflectance sampling accessory. The micro-cup of the accessory was filled with the sample diluted by anhydrous KBr to give up to 5% mixture. Spectra were collected at room temperature with a resolution of 4 cm^{-1} and 8 scans have been accumulated for each spectrum in a frequency range of 4000–450 cm^{-1}.

The organic carbon (OC), total nitrogen (TN) contents of the freeze-dried and acid-washed (1M HCl) samples were determined with a Carlo Erba model 1108 elemental analyzer (Hedges & Stern, 1984).

RESULTS AND DISCUSSION

The stromatolitic algal mat indicates the specific physico-chemical environment (Golubic *et al.*, 1977). Depending on the actual/present environmental conditions, the biogenic component of microbial mats (throughout microbially-mediated processes) conversely influences the mineral precipitation (Dupraz *et al.*, *in press*). Besides the salinity conditions, a variety of factors such as nutrients, oxygen, sulphide and concentrations, temperature, pH, light, flooding and desiccation features impacts the microbial (composition and ecological strategy/functioning) communities (Sabater *et al.*, 2000) and its organic/mineral associations. To decipher such compositional differences among the petola samples sampled during crystallization processes in summer 2006, the FT-IR spectra were obtained from bulk powdered samples (Figs. 2 and 3).

In general, all spectra (Fig. 2) are dominated by strong absorptions in O-H and N-H stretching band region (3000–3600 cm^{-1}) and in the main region for carbohydrates peaks (~1150–1000 cm^{-1}) that strongly interfere with siloxanes (Si-O) stretching (Benning *et al.*, 2004a). The organic carbon is confirmed by the IR-absorbance at 2800-3000 cm^{-1} and is most pronounced in the spectrum of sample A (June 8th). The presence of CH_2 and CH_3 alkyl groups is indicated from a stretching absorption in the 2940–2800 cm^{-1} range. The other bands of aliphatic groups that usually appear around 1429 cm^{-1} (CH_3 and CH_2 asymmetric bending) and 1385 cm^{-1} (CH_3 symmetric bending) are overwhelmed by the strong signals of calcite. The band at 1641 cm^{-1} can be assigned to Amide I signals primarily consisting of the carbonyl stretching vibration of the peptidic bond. In spectra of samples B (June 30th) and C (July 3th), this band was substituted by the signals at 1621 and 1684 cm^{-1} that can be attributed to the vibration of N-H groups of the proteins amino acids. However, groups such as aromatic and olefinic C=C (around 1650 cm^{-1}) and bending vibration from adsorbed water could be contributing factors. The lipid feature was found at ~1735 cm^{-1} (>C=O ester stretching vibrations; Benning *et al.*, 2004a), probably originating from the ester linkage of the fatty acids of Cyanobacteria representing the dominating group of petola biofilm/mat. Other C=O vibrations of ketones, organic acids and esters could add to that band.

In stromatolites, the mineral component, carbonate minerals, gypsum and halite (Dupraz *et al.*, *in press)* play important role and were emphasized in FT-IR spectra (Figs. 2 and 3) of our samples. In the dry period (Faganeli *et al.*, 1999), the organic component of petola largely combines with different minerals like quartz, feldspar, gypsum, halite, high Mg-calcite and aragonite. Clay minerals are also typically present in the petola biomat (Ogorelec *et al.*, 1981) and were very clearly indicated in sample A. Clays such as illite, smectite and kaolinite contribute to the 3620 cm^{-1} band. The presence of clay minerals suggests fine sediment trapping by microbial mats originating in marine mud basement or in material used for sanitation processes of the petola. Additionally, particles from atmospheric inputs of autochthonous and allochthonous material could also be the contributing factor.

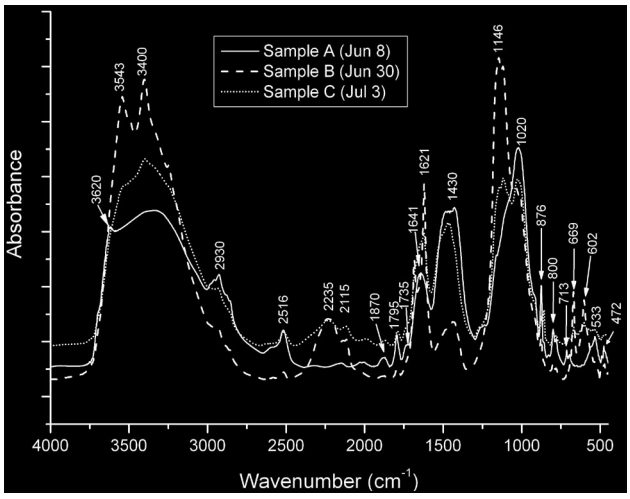

Fig. 2: FT-IR spectra of petola samples collected on June 8, June 30, and July 3, 2006. Main bands are labelled and detailed description of spectra discussed in the text.

Sl. 2: FT-IR spektri vzorcev petole vzorčenih 8. junija, 30. junija in 3. julija 2006. Označeni so glavni trakovi, podroben opis spektrov je podan v tekstu.

Spectra from all samples also display the main calcite peaks situated at 2516, 1795, 1420–1450, 876 and 712-713 cm^{-1}. Considering the previous mineralogical studies of the petola (Faganeli *et al.*, 1999; Ogorelec *et al.*, 1981, 2000), magnesium carbonate (with typical absorptions at 1482, 1420 cm^{-1} and with its much lower absorption usually located at 1120, 886, 853, 803, 719 and 593 cm^{-1}; Jackson, 2004) and aragonite also contribute to the obtained spectra. Three major bands attributed to CO_3^{2-} for the aragonite group present at 1471 cm^{-1} and two doublets around 877–848 cm^{-1} and at 713–700 cm^{-1} are marked in the spectra of sample C (Adler & Kerr, 1962; White, 1974; Guzman *et al.*, 2008). The bands around 1160 and 472 cm^{-1} belong to the silicates. The intense bands at 1150 and 1020 cm^{-1} are those of the Si-O stretching frequencies and overlapped with C-O polysaccharide frequencies. There is also a characteristic doublet with peaks at approximately 800 and 780 cm^{-1} (Pacáková *et al.*, 2000) reflecting the presence of quartz, which is also indicated by bands at 1870, 695 and 533 cm^{-1}. Comparison of the spectra obtained during petola maturation indicates significant changes in the silicate (Si-O) stretching region (1150 to 950 cm^{-1}). Instead of the maximum at ~1020 cm^{-1}, present in the spectrum of petola from sample A (June 8th), we observed the maximum peaks ~1146 and ~1030 cm^{-1} in the spectra of later samples. From those results, a degradation of carbohydrates concomitant with a modification/decrease of the silicate component (especially decrease of quartz content) could be inferred during petola cultivation/maturation. Some of those changes observed in the spectra of samples B and C are due to the crystallization of gypsum ($CaSO_4 \cdot 2H_2O$) that begins after crystallization of $CaCO_3$. The strong band centred around 1020 cm^{-1} that splits into two components at around 1146 and 1117 cm^{-1}, and the small peaks at 669 and 602 cm^{-1} are assigned to the stretching and bending mode of sulphate in gypsum. For gypsum, peaks typical of the bending vibration of O-H bond in H_2O molecule, and stretching and bending vibrations of S-O bond in SO_4^{2-} were detected at around 3543, 3407, 1683, 1621, 1141, 1118, 669 and 602 cm^{-1} (Rampazzi & Bugini, 2006; Cappitelli *et al.*, 2007). Gypsum and anhydrite sulphate could also contribute to the absorption feature at ~2235 and ~2115 cm^{-1} (Sutter *et al.*, 2005). However, the CN grouping also gives an IR signal in this region and the quartz itself as well.

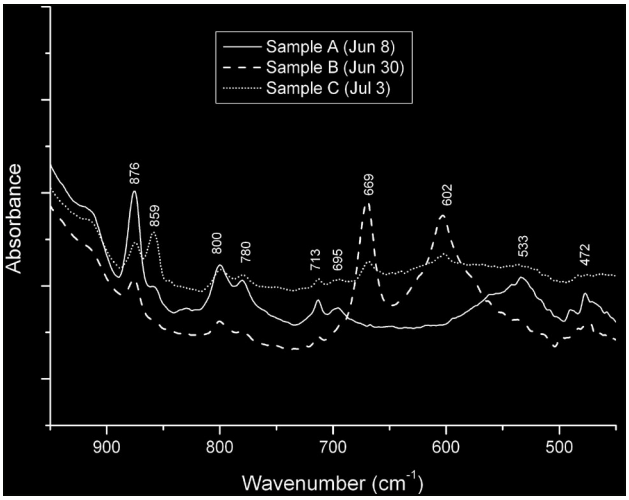

Fig. 3: FT-IR spectra of petola samples (spectral range 950–450 cm^{-1}).
Sl. 3: FT-IR-spektri vzorcev petole (spektralno območje 950–450 cm^{-1}).

The salinity data (brine) during sampling supported the presence of major salts identified by FT-IR analyses. On June 8th, the seawater concentration was approx. 5.1 °Be, which led to precipitation of $CaCO_3$, and on June 30th concentration of brine was 22.5 °Be when $CaSO_4 \cdot 2H_2O$ crystallizes (it begins at about 13.2 °Be; Korovessis & Lekkas, 2006). Evaporation of seawater finally proceeds to the halite precipitation. In the period of last sampling (sample C; July 7th, 2006), the seawater concentration in the crystallization pan was approx. 26 °Be (data from SOLINE Pridelava soli d.o.o./Salt Production Co. Ltd.), which is consistent with the crystallization of NaCl in the system. Unfortunately, the halite is known as spectrally featureless in the infrared spectra because it is transparent over much of the infrared region of the electromagnetic spectrum. Samples of halite usually give the near 100% flat absorption line, so its precipitation cannot be followed by FT-IR analyses.

During sampling the decrease of organic carbon in petola was observed. Spectra of samples sampled after 8th June obviously show decreasing absorption intensities of aliphatic CH_3 and CH_2 stretching in the 2940–2800 cm^{-1} range. The other organic absorption peaks were overlapped by main mineral absorption. The elemental analyses of petola showed similar organic carbon values as previously reported by Faganeli *et al.* (1999) (3.6–6.2%) and confirmed the above mentioned trend detected by FT-IR spectroscopy (Tab. 1).

Tab 1: Organic carbon (OC) and total nitrogen (TN) contents (wt. %), and OC/TN ratios (atomic) in the petola samples.
Tab 1: Vsebnost (ut. %) organskega ogljika (OC) in celotnega dušika (TN), in atomska razmerja OC/TN v vzorcih petole.

	Jun 8, 2006	Jun 30, 2006	Jul 3, 2006
OC	6.35	5.99	4.26
TN	0.28	0.22	0.11
OC/TN	26.96	31.75	46.01

The values for organic carbon and total nitrogen in the petola showed considerable decline. About 33% lowering of the OC content, from 6.35 to 4.26% and ~60% reductions in total nitrogen concentrations, was determined. Comparison of the OC/TN values of the petola samples during the summer indicates that bulk elemental compositions have been progressively altered by the maturation of petola and increasing brine salinity. Petola organic matter mostly derives from cyanobacteria (dominating group), diatoms and other microalgae (Faganeli *et al.*, 1999) formed *in situ* and organic matter originating in seawater (brine) above the petola biomats. Microbial community in solar salterns is a dynamic system, responding to changes in salinity and chemical environment (Litchfield *et al.*, 2009). The increasing brine salinity alters the biological composition (different microbial community structure) switches from halotolerant (stenohaline forms) to halophilic species (euryhaline forms) and could lead to reduction of microorganism biomass/growth. At Sečovlje salt-pans, the increasing brine salinity resulted in higher alteration of community structure and decrease of prokaryotic activity (Kračun, 2006). In such extremely saline environment, the cyanobacteria *Microcoleus chthonoplastes* was reported to be one of the most important species present in the petola (Schneider & Herrmann, 1980; Faganeli *et al.*, 1999). As the nitrogen content in cyanobacteria may amount up to 10% of their dry weight (Stal, 2000) and most plankton nitrogen is present as protein (Lourenço *et al.*, 1998), a preferential degradation of protein-N (in parallel with reduction in growth of microorganisms) can be suggested from our results. Protein pools, especially amino acid nitrogen (Blackburn, 1986; Burdige & Martens, 1988), are generally considered to be more labile fraction, whereas carbohydrate pools appeared to be more conservative in sediments (Dell'Anno *et al.*, 2000). Conversely, recent studies revealed that some proteinaceous material could be resistant to microbial degradation and that part of nitrogen may be preserved in sedimentary environments (Knicker & Hatcher, 2001; Nguyen & Harvey, 2001; Zang *et al.,* 2001). Additionally, the decrease of cyanobacteria accumulation of nitrogen (from sediment, brine, air) also contributes to the lower nitrogen content**.** This resulted in rather high OC/TN atomic ratios of more mature samples with low protein content and the presence of degradation products. Determined OC/TN ratio values were much higher than those reported by Faganeli *et al.* (1999), *i.e.* <10. The decrease of organic component seems to affect dropping of the silica/silicate content as the decrease of intensity of silica related bands was observed in FT-IR spectra (Fig. 3). This could relate to the lower diatom (with siliceous frustules and intracellular Si pool) and/or poorer cyanobacteria presence. Microbial surface was suggested to act as a nucleation site for silica precipitation (Konhauser, 1996; Phoenix *et al.*, 2000) and accumulation. Amorphous silica could accumulate on the surface of cyanobacteria (Benning *et al.*, 2004a, b, 2005). Aggregation of inorganically nucleated silica nanoparticles into larger silica assemblages is enhanced by exopolymeric polysaccharides (Benning *et al.*, 2005). Organic exopolymeric matrix, important component of bacterial mat, contributes also to the sediment stabilization (Klock *et al.*, 2007; Paterson *et al.*, 2008; Dupraz *et al.*, *in press).* The trapping and biding capacity of stromatolite mat community impacts the strength of the sediment and the nature of the mineralization processes (Casillas-Martinez *et al.*, 2005). Organic decay processes seem to be important for petola cementation leading to formation of a very firm substrate needed for manual gathering of salt.

Parallel to the petola analyses, we also inspected the compositional changes occurring in the dark clayey sediment just below the petola. FT-IR spectra of those samples (Fig. 4) show just minor alterations during sampling period (petola maturation). Major spectra bands of this saline mud were assigned to clay minerals (3620 cm^{-1}); O-H and N-H groups (3300–3400 cm^{-1}), aliphatic C-H stretching (2940-2800 cm^{-1}); calcite (2517, 1795, 1420–1450, 876 and 713 cm^{-1}); H_2O bending vibration, aromatic and/or olefinic C=C, proteins (1630 cm^{-1}), polysaccharide and silicate vibrations (~1150–900 cm^{-1}) and quartz (1870, 800, 780, 695, 533 cm^{-1}). The peaks located at 470 cm^{-1} and around 857 cm^{-1} could be ascribed to silicates and other carbonates (such as aragonite, Mg-carbonate etc.). A few millimetres below the petola mat, there is a border between oxic and anoxic layer (Faganeli *et al.*, 1999), so some ferric oxides (with

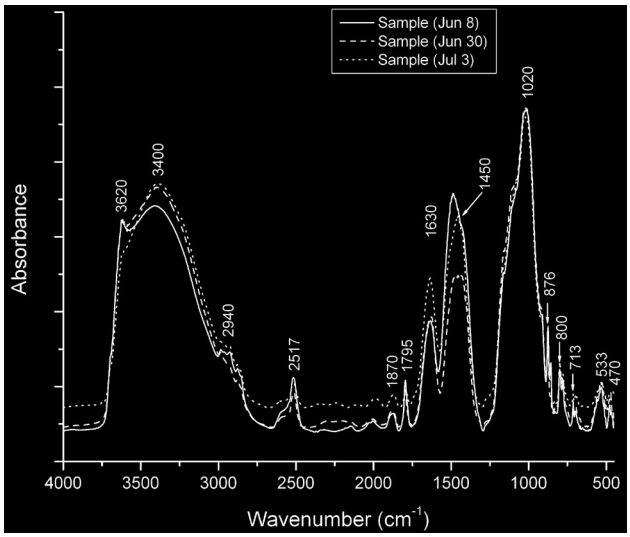

Fig. 4: FT-IR spectra of clayey sediment sampled just below petola.
Sl. 4: FT-IR-spekter glinenega sedimenta, vzorčenega pod petolo.

signals around 470 and 535–555 cm^{-1}) could contribute to those spectra. It is confirmed from these results that the studied stromatolitic mat *i.e.*, petola constitutes the most reactive surface in the salt-pans.

CONCLUSIONS

The present work confirmed the application of FT-IR spectroscopy in the studies of hypersaline system of the solar Sečovlje salt-pans. This spectroscopic technique showed modification of organic component and minerals of stromatolitic mat "petola" *i.e.*, the base layer (biosediment) of crystallization basins. With the increasing evaporation, calcium carbonate crystallized first, followed by calcium sulphate dihydrate (gypsum) and halite crystallizing at the end of evaporation. Unfortunately, the halite that crystallizes at the end of evaporation is transparent to the infrared light and does not show any lines in the spectra. The alteration of organic fraction of petola was detected during its maturation and increasing salinity concentration in crystallization basin. During the summer, the decrease of organic carbon, total nitrogen and silicate content in petola was observed. The increasing degree of cementation seems to play a very important role in the stabilization of petola, allowing manual gathering of salt on this basin's base. At the millimetre scale, petola constitutes a mainly reactive, self-sustaining system and the most important surface in saline ponds.

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KEMIČNA KARAKTERIZACIJA STROMATOLITA "PETOLA" (SEČOVELJSKE SOLINE, SLOVENIJA) Z UPORABO SPEKTROSKOPIJE FT-IR

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POVZETEK

Stromatolitska plast, imenovana "petola", je v Sečoveljskih solinah (Tržaški zaliv, severni Jadran) osnovni substrat za tradicionalno ročno pridelavo soli, zato je poznavanje njenega kemizma pomembno za ohranitev in razvoj te aktivnosti. Sestavo in spremembe petole smo preučevali s pomočjo spektrov FT-IR homogeniziranih celotnih vzorcev. Glavne anorganske komponente sestavljajo karbonati, sadra ($CaSO_4 \cdot 2H_2O$) in silikati, organska frakcija pa se pojavlja v manjšem deležu (OC; 4,3–6,4 ut. %). Med vzorčevanjem, tj. v času zorenja petole in porasta slanosti slanice, smo zasledili padec koncentracije silikatov, organskega ogljika (OC) in celotnega dušika (TN) ter porast OC/TN atomskega razmerja. Opisana raziskava potrjuje uporabnost spektroskopije FT-IR pri preučevanju sestave in pretvorb petole ter bazičnih raziskavah hipersalinih območij.

Ključne besede: stromatolit-petola, FT-IR, elementna sestava, Sečoveljske soline, severni Jadran

REFERENCES

Adler, H. H. & P. F. Kerr (1962): Infrared study of aragonite and calcite. Am. Mineral., 47, 700–717.

Benning, L. G., V. R. Phoenix, N. Yee & M. J. Tobin (2004a): Molecular characterization of cyanobacterial silicification using synchrotron infrared micro-spectroscopy. Geochim. Cosmochim. Acta, 68, 743–757.

Benning, L. G., V. R. Phoenix, N. Yee & K. O. Konhauser (2004b): The dynamics of cyanobacterial silicification: An infrared micro-spectroscopic investigation. Geochim. Cosmochim. Acta, 68, 729–741.

Benning, L. G., V. Phoenix & B. W. Mountain (2005): Biosilicification: the role of cyanobacteria in silica sinter deposition. In: Gadd, G. M., K. T. Semple & H. M. Lappin-Scott (eds.): Micro-organisms and earth systems –

advances in geomicrobiology. Society of General Microbiology Symposium, Cambridge University Press, pp. 131–150.

Blackburn, T. H. (1986): Nitrogen cycle in marine sediments. Ophelia, 26, 65–76.

Burdige, D. J. & C. S. Martens (1988): Biogeochemical cycling in an organic-rich coastal marine basin: 10. The role of amino acids in sedimentary organic carbon and nitrogen cycling. Geochim. Cosmochim. Acta, 52, 1571–1584.

Cappitelli, F., L. Toniolo, A. Sansonetti, D. Gulotta, G. Ranalli, E. Zanardini & C. Sorlini (2007): Advantages of Using Microbial Technology over Traditional Chemical Technology in Removal of Black Crusts from Stone Surfaces of Historical Monuments. Appl. Environ. Microbiol., 73, 5671–5675.

Casillas-Martinez, L., M. L. Gonzalez, Z. Fuentes-Figueroa, C. M. Castro, D. Nieves-Mendez, C. Hernandez, W. Ramirez, R. E. Sytsma, J. Perez-Jimenez & P. T. Visscher (2005): Community structure, geochemical characteristics and mineralogy of a hypersaline microbial mat, Cabo Rojo, PR. Geomicrobiol. J., 22, 269–281.

Dell'Anno, A., M. Fabiano, M. L. Mei & R. Danovaro (2000): Enzymatically hydrolysed protein and carbohydrate pools in deep-sea sediments: estimates of the potentially bioavailable fraction and methodological considerations. Mar. Ecol. Prog. Ser., 196, 15–23.

Dolenec, T., J. Kink, J. Pezdič, B. Ogorelec & J. Faganeli (1994): Oxygen and carbon isotopic composition of holocene sediment from the salt marsh of Sečovlje (Gulf of Trieste). International Association of Sedimentologists. Book of Abstracts. Ischia, pp. 160–161.

Dupraz, C., R. P. Reid, O. Braissant, A. W. Decho, R. S. Norman & P. T. Visscher (2009): Processes of carbonate precipitation in modern microbial mats. Earth-Science Reviews. *(In press)*

Faganeli, J., J. Pezdič, B. Ogorelec, T. Dolenec & B. Čermelj (1999): Salt works of Sečovlje (Gulf of Trieste, northern Adriatic) – a sedimentological and biogeochemical laboratory for evaporitic environments. RMZ – M&G, 46, 491–499.

Golubic, S., T. Le Campion-Alsumard & J. Schneider (1977): The salt works of Sečovlje (Portorož, Yugoslavia), a natural model for geochemistry and microbiology of evaporitic environments. Rapp. Comm. int. Mer. Médit., 24, 125–126.

Guzman, N., Y. Dauphin, J. P. Cuif, A. Denis & L. Ortlieb (2008): Diagenetic changes in *Concholepas concholepas* shells (Gastropoda, Muricidae) in the hyperarid conditions of Northern Chile – implications for palaeoenvironmental reconstructions, Biogeosci. Discuss., 5, 501–530. http://www.biogeosciences-discuss.net/5/501/2008/bgd-5-501-2008.pdf (March 2, 2009)

Hedges, J. I. & J. H. Stern (1984): Carbon and nitrogen determinations in carbonate-containing solids. Limnol. Oceanogr., 29, 657–663.

Jackson, K. D. O. (2004): A guide to identifying common inorganic fillers and activators using vibrational spectroscopy, The Internet Journal of Vibrational spectroscopy [online computer file], 2(3), no pp given. http://www.ijvs.com/volume2/edition3/section3.html; accessed 23.1.2009

Klock, J.-H., A. Wieland, R. Seifert & W. Michaelis (2007): Extracellular polymeric substances (EPS) from cyanobacterial mats: characterisation and isolation method optimisation. Mar. Biol., 152, 1077–1085.

Knicker, H. & P. G. Hatcher (2001): Sequestration of organic nitrogen in the sapropel from Mangrove lake, Bermuda. Org. Geochem., 32, 733–744.

Konhauser, K. O. & F. G. Ferris (1996): Diversity of iron and silica precipitation by microbial mats in hydrothermal waters, Iceland: implications for Precambrian iron formations. Geology, 24, 323–326.

Korovessis, N. A. & T. D. Lekkas (2006): Comparison of Solar Saltworks with saline coastal wetlands. In: Lekkas, T. D. & N.A. Korovessis (eds.): Proceedings of the 1st International Conference on the Ecological Importance of Solar Saltworks, October 20–22, 2006, Santorini Island. Global Nest, Athens, Greece, pp. 52–61.

Kračun, N. (2006): Structure and activity of microbial community along salinity gradient of Sečovlje salterns. B. Sc. Thesis. Biotechnical Faculty, University of Ljubljana, Ljubljana. *(In Slovene)*

Litchfield, C. D., A. Oren, A. Irby, M. Sikaroodi & P. M. Gillevet (2009): Temporal and salinity impacts on the microbial diversity at the Eilat, Israel, solar salt plant. Global NEST J., 11, 86–90.

Lourenço, S. O., E. Barbarino, U. M. Lanfer-Marquez & E. Aidar (1998): Distribution of intracellular nitrogen in marine microalgae: basis for the calculation of specific nitrogen-to-protein conversion factors. J. Phycol., 34, 798–811.

Meischner, D. & J. Rumohr (1974): A light-weight high-momentum gravity corer for subaqueous sediments. Senckenb. Marit., 6, 105–117.

Nguyen, R. T. & H. R. Harvey (2001): Preservation of protein in marine systems: Hydrophobic and other non-covalent associations as major stabilizing forces. Geochim. Cosmochim. Acta, 65, 467–1480.

Ogorelec, B., M. Mišič, A. Šercelj, F. Cimerman, J. Faganeli & P. Stegnar (1981): Sediment Sečoveljske soline = Sediment of the salt marsh of Sečovlje. Geologija, 24, 179–216.

Ogorelec, B., M. Mišič & J. Faganeli (2000): Sečoveljske soline – geološki laboratorij v naravi. Annales, Ser. Hist. Nat., 10(2), 243–252.

Pacáková, V., D. Pockevičite, S. Armalis, K. Štulik, J. Li & J. Vaselý (2000): A study of the distribution of lead, cadmium and copper between water and kaolin, bentonite and river sediment. J. Environ. Monit., 2, 187–191.

Paterson, D. M., R. J. Aspden, P. T. Visscher, M. Consalvey, M. Andres, A. W. Decho, J. Stolz & P. R. Reid (2008): Light-dependant biostabilisation of sediments by stromatolite assemblages. PLoS One, 3(9), e3176.

Phoenix, V. R., D. G. Adams & K. O. Konhauser (2000): Cyanobacterial viability during hydrothermal biomineralisation. Chem. Geol., 169, 329–338.

Rampazzi, L. & R. Bugini (2006): St. Lorenzo basilica in Milan: Integral approach to characterization of historical mortars. e-PS, 3, 21–26.

Sabater, S., A. M. Romaní, H. Guasch & I. Muñoz (2000): Stromatolitic communities in Mediterranean streams: Adaptations to a changing environment. Biodivers. Conserv., 9, 379–392.

Schneider, J. & A. G. Herrmann (1980): Saltworks natural laboratories for microbiological and geochemical investigation during the evaporation of seawater. 5th International Symposium on Salt-Northern Ohio Geological Society, Vol. 2, pp 371–380.

SOLINE Pridelava soli d.o.o. (Salt Production Co. Ltd.) – basic information. http://www.soline.si/company (January 6, 2009)

Stal, L. J. (2000): Cyanobacterial mats and stromatolites. In: Whitton, B. A. & M. Potts (eds.): The Ecology of Cyanobacteria. Kluwer Academic Publishers, Dordrecht, the Netherlands, pp. 61–120.

Sutter, B., J. B. Dalton, S. A. Ewing, R. Amundson & C. P. McKay (2005): Infrared spectroscopic analyses of sulphate, nitrate, and carbonate-bearing Atacama Desert soils: Analogs for the interpretation of infrared spectra from the Martian surface. Lunar and Planetary Science. http://www.lpi.usra.edu/meetings/lpsc2005/pdf/2182.pdf (February 2, 2009)

White, W. B. (1974): The carbonate minerals. In: Farmer, V.C. (ed.): The Infrared spectra of minerals. Mineralogical Society of London Monograph, 4, 227–284.

Zang, X., R. T. Nguyen, H. R. Harvey, H. Knicker & P. G. Hatcher (2001): Preservation of proteinaceous material during the degradation of the green alga *Botryococcus braunii*: A solid-state 2D ^{15}N ^{13}C NMR spectroscopy study. Geochim. Cosmochim. Acta, 65, 3299–3305.

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TOPOCLIMATIC CONDITIONS AS FACTORS, INFLUENCING ON THE OLIVE GROWING IN THE MUNICIPALITY OF PIRAN

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ABSTRACT

The author analyses and evaluates the influence of the selected physical geographic factors on olive growing in the Municipality of Piran. The spatial distribution of olive groves in the area in relation to the chosen relief factors (elevation, slope and aspect) has shown that most of the olive groves are situated at the sites classified as very suitable for them: 98% in the elevation zone up to 250 m a.s.l., almost 40% on slopes with less than 20%, while almost 60% of the groves are situated at southern and south-western aspect sites. The answers given by the questionnaired olive oil producers have furthermore pointed out a certain impact of the olive grove aspect on crop size and frost threat. This, however, is difficult to define, considering that olive growing is influenced by many different factors, such as olive age and variety, as well as agronomic factors, e.g. olive grove cultivation.

Key words: olive growing, Municipality of Piran, GERK, frost, elevation, slope, aspect

CONDIZIONI TOPOCLIMATICHE QUALI FATTORI INFLUENZANTI LA CRESCITA DI OLIVI NEL COMUNE DI PIRANO

SINTESI

Gli autori analizzano e valutano l'influenza di determinati fattori fisico-geografici sulla crescita degli olivi nel comune di Pirano. La distribuzione spaziale delle piantagioni di olivi in relazione ai fattori topoclimatici prescelti (altitudine, inclinazione ed esposizione della superficie) ha evidenziato che gran parte delle piantagioni è situata in siti classificati quali molto idonei: il 98% dei quali in zone fino a 250 m s.l.m., almeno il 40% in zone con inclinazione inferiore al 20%, e quasi il 60% delle piantagioni è situato in siti esposti a sud e sud-ovest. Le risposte al questionario fornite dagli olivicoltori hanno inoltre evidenziato un determinato impatto dell'esposizione delle piantagioni sulla produttività annuale e sul rischio di gelate. Tale impatto è però difficile da definire e quantificare, considerando che la crescita degli olivi viene influenzata da diversi fattori, quali l'età e la varietà dell'olivo, nonché da svariati fattori agronomici.

Parole chiave: crescita olivi, comune di Pirano, GERK, gelata, altitudine, inclinazione, esposizione

INTRODUCTION

The article focuses on olive growing in the Municipality of Piran, comprising the chosen relief (physical geographic) factors. It presupposes that in respect of physical geographic factors, the Municipality as part of Slovene Istria constitutes an area where the olive-growing conditions are favourable. Based on these assumptions, the article has the following two main goals:

- to present the spatial distribution of olive groves as a category of land use in the Municipality of Piran in relation to the selected relief factors;
- to evaluate the impact the olive grove aspect has on crop size and frost threat.

Physical and social geographic factors influencing olive growing

Olive is a Mediterranean tree, thriving especially in the Mediterranean climate regions, known for their warm and dry summers and mild and wet winters (Vesel, 1998). In Slovenia, olive tree regions correspond with the sub-Mediterranean climate. Slovene Istria is the principle olive tree region in Slovenia (98% of all olive groves in Slovenia are found here), followed by the region of Goriška Brda Hills and the Vipava River valley with only 2% (Ogrin, 2004). The total surface of olive groves in Slovenia is estimated at about 1,561 ha (Bandelj Mavsar *et al.*, 2008). Considering Slovenia's geographic position, bearing in mind its latitude (45-46°N), the olive groves here reach their northernmost position, thus being endangered especially by winter frosts (Ogrin, 2004).

We estimate that the following physical geographical factors predominantly control olive growing in Slovenia:

- Temperature: in Slovenia, minimal winter temperatures represent the most obvious limit (Ogrin, 2002), being influenced also by the high air humidity and frost duration. Olives are more vulnerable to frost when the latter lasts longer and the air is more humid.
- Precipitation: Although the olive is considered to be adapted to the rainfall shortage, it can be prone to the lack of water during and after the blossoming (in May and months after), but also while forming its stone (July). A sufficient amount of water is needed also in autumn for cell forming and ripening (Vrhovnik, 2007).
- Wind condition: A gentle breeze is a favourable condition during the blossoming and ripening of the fruits, as it speeds up the pollination. On the other hand, strong dry winds can severely damage the trees situated at more exposed locations (Sancin, 1990).
- Daylight: In Slovenia, this factor does not present a serious limitation to olive growing, since the Slovene littoral and its nearby hinterland cover the areas receiving the highest amount of solar radiation in the country (Gams, 1998).
- Rock (soil) type: A hard, humid, clayey soil is less favourable for the olive tree, as it can suffocate its roots as a result of the lack of oxygen (Sancin, 1990).

The present article focuses on the topoclimatic geographic factors, such as relief elevation, slope and aspect. Since air temperature is controlled by the elevation, the latter is a very important influencing factor on olive tree growing in Slovenia. In the littoral area, air temperatures decrease towards the hinterland. One of the reasons is the Adriatic Sea, being 2°C warmer than the surrounding air on the yearly average (Ogrin, 1995).

The olive growing in Slovenia is also influenced and controlled by the social geographical factors. The most recognizable and important among them are (Bandelj Mavsar *et al.*, 2008):

- plots of land are small; as the estimated average size of an olive grove is less than 0,5 ha, they are less appropriate for more intensive agriculture;
- plots are very fragmented;
- administrative matters regarding land registers are mostly unregulated;
- many of the plot owners reside abroad;
- olive oil is not as interesting market product as wine;
- high costs of setting up olive groves, especially in steep terrain;
- insufficient financial aid for laying out new olive groves.

A geographical overview of the Municipality of Piran

The municipality of Piran, which covers some 45 km^2, is situated in the south-westernmost part of Slovenia. Its population is almost 18.000, with the majority living in the towns (Razvojni program podeželja za območje občin Koper, Izola in Piran, 2006). The municipality is divided into 5 cadastral units: Portorož, Piran, Sečovlje, Raven and Nova vas (3MAP, 2008). Together with the Municipalities of Izola and Koper, it forms the geographic unit named Slovene Istria (Ogrin, 1995).

According to the climatic criteria, the biggest part of the Piran Municipality is situated in the littoral zone (Ogrin, 1995) to the height of 200–250 m. The area is influenced by the Adriatic Sea, which lowers temperature extremes both in the winter and summer periods. Thus, the conditions for olive tree growing are highly suitable, as the winter or early spring frosts usually do not pose a serious threat to them. However, they can be subjected to strong winds (bora, jugo) (Ogrin, 1995).

The leading economic activity in the Municipality is tourism with fishery being the supplementary branch, as well as salt production and agriculture. The area is well known for its Mediterranean vegetable cultures, olives and vine (Razvojni program podeželja za območje občin Koper, Izola in Piran, 2006).

MATERIAL AND METHODS

To achieve the goals stated in the introductory part, we used two main methodological tools. Firstly, we used the GIS (Geographic information system) to assess spatial distribution of olive groves in the Municipality of Piran in relation to the relief-topoclimatic factors: elevation, slope and aspect. Secondly, questionnaires were carried out to examine whether the olive grove aspect has an impact on crop size and frost threat.

The slope basically tells us how steep a defined area is; it is a quotient between height change and distance between two chosen points on the surface. When this quotient is multiplied by 100, we get the slope incline in %. The aspect tells us the direction faced by hill slopes. It has a major impact on how the relief is exposed to the daylight. The aspect is classified according to the cardinal points (N, NE, E, SE, S, SW, W, NW), with each of them containing the degree interval of 45 (by ArcMAP, 2008) *(e.g.*, 0–22.5° and 337.5–360° for north direction, 22.5–67.5° for northeast, 67.5–112.5° for east, 112.5–157.5° for southeast, 157.5–202.5° for south, 202.5–247.5° for southwest, 247.5–292.5° for west, and 292.5–337.5° for northwest).

The groundwork of the map was represented by the following layers:

- Piran municipality vector map, consisting of outline borders, major towns (points) and water resources (obtained by GIAM, 2007);
- Piran municipality Digital elevation model (12,5 m) (obtained by GURS, 2007);
- GERK (The Registry of the husbandries) olive grove stats as a category of land use (obtained by MKGP, 2008).

Each of the relief factors was classified into three quality ranks or positions, theoretically determining the conditions of the olive grove (Tab. 1).

Tab. 1: Quality ranks of the chosen physical geographic factors.
Tab. 1: Kakovostni razredi izbranih naravnogeografskih dejavnikov.

Positions \ Factor	Elevation (m)	Slope (%)	Aspect
Very suitable	0–100	0–20	S, SW
Medium	100–250	20–30	W, SE
Less suitable	above 250	above 30	E, N, NW, NE

The quality positions were stipulated according to the prevailing literature sources. The elevations up to 250 m are usually the highest where the conditions for olive trees are still optimal (Lubi, 2001). In general, we estimate that lower elevations are more favourable for olive trees, although olives can be exposed to temperature inversion at very low elevations (Ogrin, 1995). We also estimate that steeper slope makes the conditions for olive cultivation harder and more expensive (Jančar *et al.*, 2002) in terms of agricultural engineering. The classification of the aspect ranks is based on the solar radiation level table (Gabrovec, 1996), by which the southern and south-western positions are characterized as the most sun-exposed ones, whereas the northern positions are the least. The eastern positions are mostly subjected to the strong and cold winds (bora) and are thus considered less appropriate for olive trees, even if they are south-orientated (Lubi, 2001). The trees on south-eastern positions are exposed to sun rays for most of the day, which is fairly favourable, but can warm the trunk and branches, causing earlier sap circulation before the vegetation starts. This, however, can be fatal in the event of frost. Olive trees located on western and also northern positions are, by contrast, subjected to lower temperatures. The later start of their vegetation period makes the trees more resistant to frost (Lubi, 2001). As a result, a category of south–eastern positions was recognized as the middle quality rank.

Questionnaires

34 olive oil producers in the Municipality of Piran were included in the survey carried out with questionnaires. The idea was that the survey sample should cover different olive grove aspects (positions) as specified above. The respondents' contact addresses were provided by the MKGP. However, the list of olive oil producers in this register is not complete, since only the owners who have voluntarily subscribed to the national husbandry register (GERK) are listed. Regarding this fact, the survey took into account only about one third of the total olive groves surface in the investigated area. Nevertheless, the register provides good information on the aspects, slopes, olive groves age and plant numbers of the particular groves. While making sample list of the olive oil producers regarding the aspect classification of their olive groves, we took into consideration that each aspect category (very, medium and less suitable) has an adequate number of respondents. However, the investigation revealed that the number of respondents as owners of olive groves characterized as "less suitable" in the survey was not adequate. Some respondents from the Municipalities of Izola and Koper were thus included into the survey.

Phone interviews with 34 respondents were made, revealing that a half of the olive oil producers possess olive groves that lie fully in a single aspect category. The other half have their olive groves located in different quality positions (with different aspects). For example, one farmer has an olive grove on the southern (very suitable) as well as on the eastern (less suitable) position. This group (Group 2) is to be discussed separately from

the former (Group 1) and it is to be later put into the following categories of aspect quality or suitability: less, middle and very; less and middle; middle and very; less and very suitable.

The questions, which were of open type, were as follows:

- estimate of the average yearly crop size in kg per tree;
- for the farmers with olive groves on different quality localities (aspects): do they estimate that the yearly crop size differs according to the grove aspect and why, how do they rate the impact the aspect has on the crop size;
- the previous experience with frosts, their degree and damage;
- remarks (about grove cultivation, etc.).

Question type and a great diversity of answers provided almost no chance for a serious quantitative analysis, but some summarized results were nevertheless obtained.

RESULTS

Map of spatial distribution of olive groves in the Municipality of Piran

According to the MKGP (as of November 2007), the Municipality of Piran encompasses approximately 414 ha of olive groves. The majority of them are found in a belt extending in NW-SE direction from Seča to Parecag. Note also the zone above Lucija and south from Strunjan. The eastern part of the Municipality is higher in elevation and includes the olive groves around bigger villages such as Padna, Nova vas, Sveti Peter and Dragonja. Due to the saltpans, it is not surprisingly that practically no olives can be found south of Sečovlje. A similar analysis of the actual agricultural land use in Slovenia (in Bandelj Mavsar *et al.*, 2008) made in 2002 has shown that the Municipality of Piran comprises 324 ha of olive groves. The Municipality of Koper boasts almost twice that number (635), while Izola reaches only a half of it (173 ha).

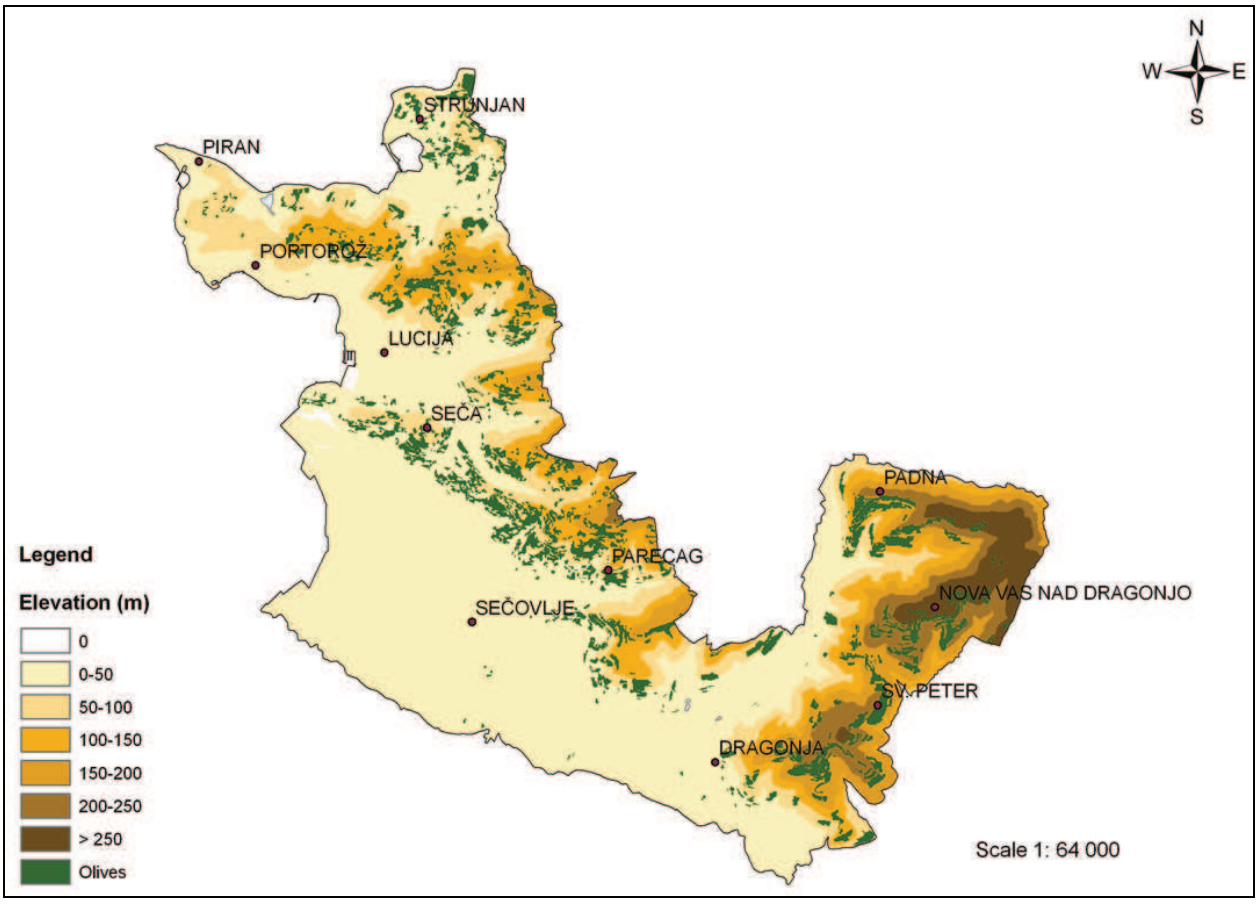

Fig. 1: The municipality of Piran: distribution of olive groves according to elevation (cartography: A. Majer; sources: GIAM, 2007; GURS, 2007; MKGP, 2008).
Sl. 1: Občina Piran: razporeditev oljčnikov po nadmorskih višinah (kartografija: A. Majer; viri: GIAM, 2007; GURS, 2007; MKGP, 2008).

Tab. 2: The Municipality of Piran: distribution of olive groves according to elevation (sources: GIAM, 2007, GURS, 2007, MKGP, 2008).
Tab. 2: Občina Piran: razporeditev oljčnikov po nadmorskih višinah (viri: GIAM, 2007, GURS, 2007, MKGP, 2008).

Elevation (m)	% of surface	% of olive groves
0–100	72.2	52.6
100–250	24.9	45.2
above 250	2.9	2.2

Three quarters of the Municipality of Piran are situated at altitudes between 0–100 meters above sea level and more than a half at the elevations of up to 50 m a. s. l.

Tab. 3: The municipality of Piran: distribution of olive groves according to slope (sources: GIAM, 2007, GURS, 2007, MKGP, 2008).
Tab. 3: Občina Piran: razporeditev oljčnikov po naklonih (viri: GIAM, 2007, GURS, 2007, MKGP, 2008).

Slope (%)	% of surface	% of olive groves
0–20	59.5	39.8
20–30	14.4	31.9
above 30	26.2	28.3

The categories of slopes are more evenly distributed (Tab. 3, Fig. 2). The majority or almost 40% of the groves lie in the up to 20% category (villages of Seča, Dragonja and Strunjan), where the agricultural conditions are considered more favourable or very suitable. The middle zone (20-30% slope) is also well present.

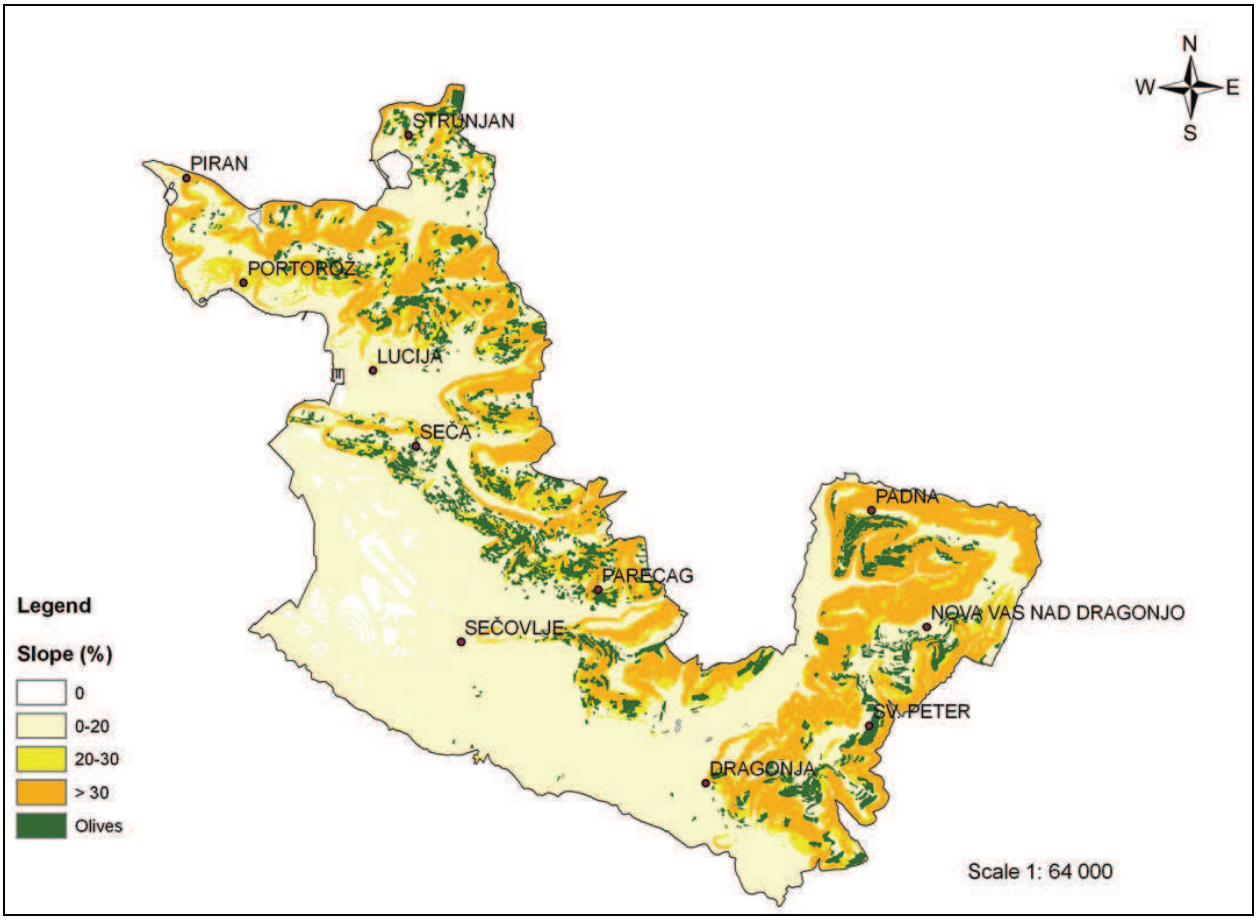

Fig. 2: The municipality of Piran: distribution of olive groves according to slope (cartography: A. Majer; sources: GIAM, 2007; GURS, 2007; MKGP, 2008).
Sl. 2: Občina Piran: razporeditev oljčnikov po naklonih (kartografija: A. Majer; viri: GIAM, 2007; GURS, 2007: MKGP, 2008).

The zone with slopes higher than 30% and considered less suitable for olive trees corresponds to the surface of 28% groves (villages of Parecag and Padna). In the latter category, the conditions for setting up and maintaining olive trees are not only harder but also more expensive in the sense of agricultural engineering.

Tab. 4: The municipality of Piran: distribution of olive groves according to aspect (sources: GIAM, 2007, GURS, 2007, MKGP, 2008).
Tab. 4: Občina Piran: razporeditev oljčnikov po ekspozicijah (viri: GIAM, 2007, GURS, 2007, MKGP, 2008).

Aspect	% of surface	% of ol. groves
S, SW	34.3	58.8
W, SE	22.8	25.8
E, N, NW, NE	42.9	15.4

In the Municipality of Piran, southern and south-western aspect locations (both being classified as very suitable) prevail, jointly comprising one third of the total municipality surface area (Tab. 4, Fig. 3). The majority of olive groves belonging to this category reside in the north-western and central parts of the Municipality. In the grouping sense, though, they are being outnumbered by less suitable locations (43%). The latter are part of the north-western aspect location near the villages of Padna, Nova vas and Sveti Peter.

In contrast, when linking the surface area with the olive grove sites, the prevalent pattern of olives being grown at very suitable localities is again shown. With 34% of the municipality surface area, the zone of the southern and south-western aspect locations is host to almost 60% of olive groves (olive belt between Seča and Parecag, east of Portorož and above Lucija). This is also the case of the Municipality's higher eastern part (Padna, Dragonja and Nova vas). A quarter of the olive tree surface area is situated on the western and south-eastern aspect locations. The northern and eastern aspect locations comprise only one sixth of the olive grove surface area, despite comprising the largest part of the municipality surface.

Questionnaire survey results

The survey results were very diverse and also revealed some methodological shortcomings of our research. First of all, the interdependence between the olive crop size and the olive grove aspect was not shown as an absolute one. Respondents listed different factors possibly influencing the crop size of olive groves and thus revealed to us that we might have overestimated the aspect of the olive grove site as a factor influencing the olive crop size. That is why we believe the relative differences between crop sizes would be more meaningful, although the factors taken into account by respondents are more significant. As noted above, they were split into two groups.

Aspect does have some impact on the olive crop size; however, it is difficult to measure it. The answers from the latter group (Group 2), when the farmers had an easier task of comparing the crop size from different groves, characterised by different aspects, pointed out the olive variety and its age as the most important factors (mentioned 7 or 6 times). The aspect was mentioned 6 times, the cultivation type 5 times. Other factors mentioned were also: soil and "various" (twice) and drought, humidity, human factor, elevation, no answer / I do not know.

The farmers, questioned and put into Group 1, had some difficulties when evaluating the aspect's impact on crop size (7 did not provide an answer), as their experience with different quality aspects had been diminished. However, they again stressed the influence of the olive age (7 farmers mentioning it) and variety (6) on crop size. In general, when the olive tree is older, it gives more crops; but this is also the case with varieties such as Istrska belica or Leccino. Other factors mentioned were: aspect, drought and cultivation type (2) and illness, microclimate, frost, planting distances and soil type (1 answer each). Apart from these factors, it is important to remark that olives are being endangered also by spring drought, although barely noticeable in the respondents' answers. It is definitely a surprising remark, since the olive has always been known as a plant resistant to different external factors, and thus also to droughts. It seems that in the last couple of years the farmers have been advised to irrigate their groves (Vrhovnik, 2007).

Generally speaking, an average olive crop size of a single tree yields around 20–25 kg of fruits, younger trees giving less (5–15 kg) and older more (also more than 70 kg) fruits per tree.

The results also showed the impact exerted by the olive grove aspect locality on frost endangerment. Olive groves located on less suitable (or/and medium) positions are more prone to frost. Frost was experienced by 80% of farmers having their groves on less suitable locations (Group 1) and by 100% of them having their groves on less and medium suitable positions (Group 2). However, this does not mean that the groves situated on theoretically more favourable aspects are not endangered, too. The percentage of farmers (Group 1) experiencing frost was higher in the category of very suitable (38) than on medium suitable aspect locations (25). In Group 2, the second highest percentage of frost occurrence appeared in the aspect category classified as less and very suitable (75), in the other two categories (less, medium, very; medium and very) it was 50. The results do not show, however, that the farmers, like in the previous situation, again stressed the importance of age and

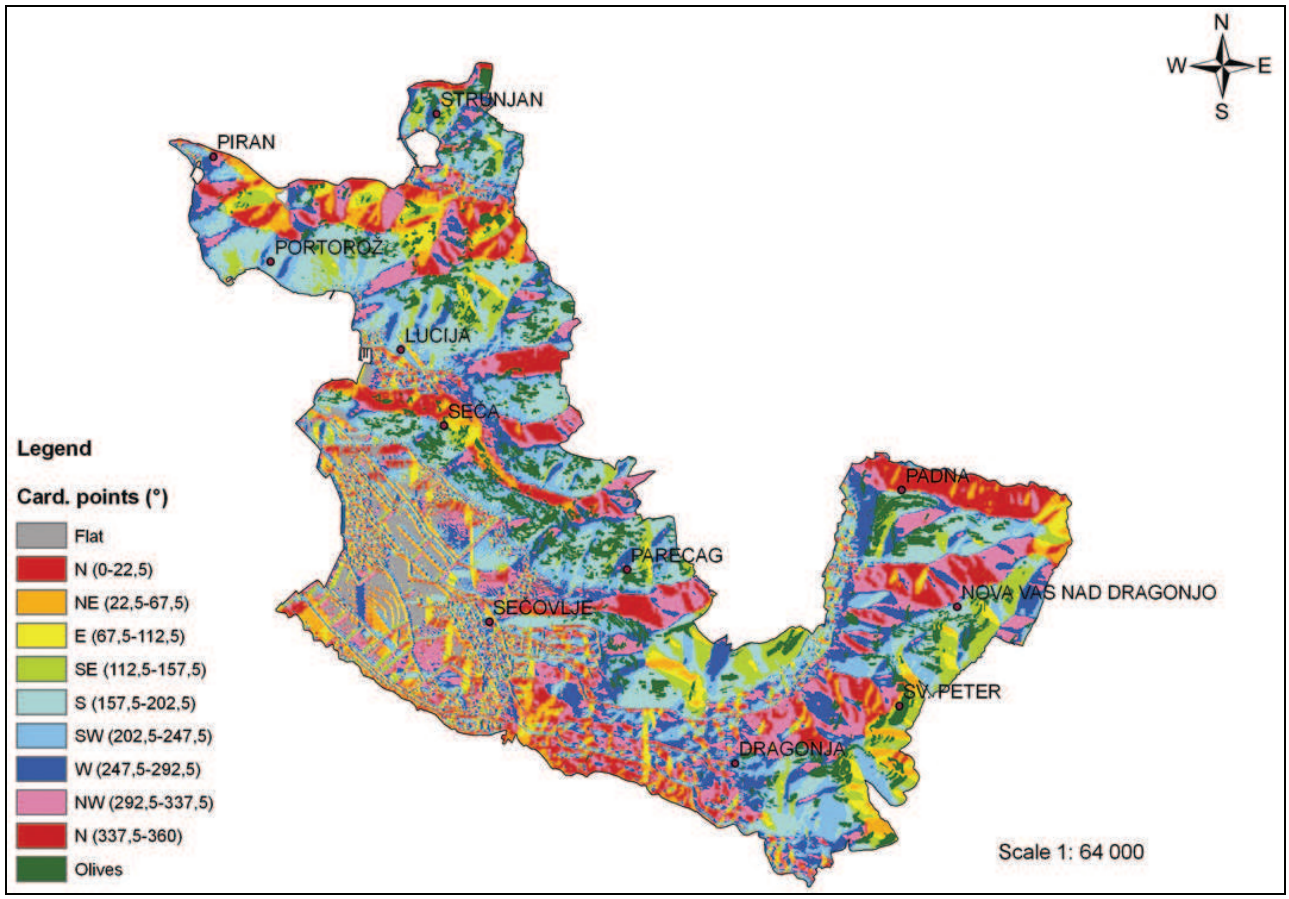

Fig. 3: The municipality of Piran: distribution of olive groves according to aspect (cartography: A. Majer; sources: GIAM, 2007; GURS, 2007; MKGP, 2008).
Sl. 3: Občina Piran: razporeditev oljčnikov po ekspozicijah (kartografija: A. Majer; viri: GIAM, 2007; GURS, 2007; MKGP, 2008).

variety of the olive tree in regard to frost endangerment. Older trees seem to be less prone to it, as well as some varieties such as Istrska belica.

DISCUSSION

It seems that the core answer of our research would reside in the broad category of "various factors". Not only that the factors are various, the important thing is also the time and type of an impact they possess by having an impact on crop size and frost threat. As these factors are both natural (variety, aspect, age) and social/economic (planting distances, plant material, type of cultivation etc.) we must also stress the importance of the human factor. Without suitable education and micro-management, such as cultivation, protection etc., the crop size will be less than satisfying, despite the fact that olive groves hypothetically inhabit the most favourable sites on Earth. A number of such cases were revealed in our survey; the most obvious concerning a farmer, who a season ago had much more crop in a theoretically less favourable east-orientated grove than in the southern one. The reason was bad cultivation, but also the greater impact of drought, which seemed to affect the grove on the southern aspect.

Quite opposite situations also occurred, *i.e.* some groves had managed to survive despite their theoretically less suitable location (an example is the farmer with a 300-year old grove on the western to northern orientation). In this respect, we believe that our aspect classification according to the cardinal points is possibly too accurate and that it should be more simplified. For example, a difference of 5 angle degrees can mean two totally different quality aspects, which is in practice almost unlikely.

From the other point of view, the results of the first part of our research in spatial distribution of olives in the Municipality of Piran certainly indicate prevalence of olive groves situated on very suitable locations. It is, in fact, in the category of aspect, where the differences show the most obvious pattern. The same as we stated the significance of the human factor above, we must at

the end also stress the importance of the physical geographic factors influencing olive growing, with both categories viewed as a whole. We can presuppose that the farmers had obviously known the favourable locations for planting their olive trees, and had obviously taken this well into account.

It would be inappropriate not to mention the opinion of one of the well-known oil producer in Slovenia, actually making the whole point of this topic.

In his opinion, the olive tree fertility is influenced concurrently by several factors. Without a thorough research (bearing in mind the pre-planting soil cultivation, plant material and planting distances, olive varieties, fertilization, tree cutting), it is thus very hard to pinpoint the cause of lesser fertility to only a single factor. He believes that this can also be ascribed to the site aspect, but only in case of big deviations in the crop size when compared to more favourable sites. He also believes that a less suitable aspect can decrease the tree fertility in the seasons with winter marked by both severe frost and bora wind, as well as during the years when harsh conditions such as heat, drought and bora are experienced during the blooming period (causing low effective fructification in plants). Otherwise he does not see significant differences in crop size, which would be the case of aspect location. If claiming the opposite, one should eliminate other factors, which are in his opinion more important, especially the density of planted trees, planting distances and quality planting material that outclass the favourable climate and soil conditions (V. Dujc, *pers. comm.*).

CONCLUSIONS

Physical geographic characteristics of Slovene Istria, including the Piran Municipality, determine the latter as an area with very favourable conditions for olive growing. The spatial distribution of olive groves is in relation to the specific topoclimatic factors: elevation, slope and aspect. To summarize: 98% of olive groves are located in the elevation zone of up to 250 m, almost 40% of them are situated on slopes with less than 20%, and almost 60% on southern and south-western aspect locations. In all three categories, these numbers constitute the majority, so we can conclude that olive groves in the Municipality of Piran can theoretically boast very good and very suitable relief conditions.

In practice, however, the results of our survey in which we tried to evaluate the impact exerted by the grove aspect on crop size and crop threat, has furthermore shown the following premises about the olive growing:

- a vast number of factors influence olive growing;
- these factors can have a simultaneous effect, and if we assess one of them, others have to be also considered (directly), although some can be or must be eliminated;
- even if these factors have a simultaneous effect, the extent of their impact will be related to their duration and time of occurrence (e.g. macro- and microclimate factors).

All this would be also taken into account if we decided to associate the elevation or slope with the crop size, instead of the aspect. For an applicable analysis, one should firstly highlight a single factor while eliminating the others. All this would require much knowledge from the fields of agronomy, aeromechanics and agriculture, which of course exceeds the topic of our research.

Two important factors regarding the crop size and frost threat have been revealed by the research: olive age and variety. Older olives have better fertility and are less prone to frost; the same can be said of some well known varieties, such as Istrska belica. Regarding the frost, no aspect can provide for the plants' 100% protection; on more south orientated slopes its impact can, perhaps, be minimised.

One of the decisive issues that should not be overlooked is the human factor. The same as we can classify *e.g.*, elevation or slope as very or less suitable, we can also classify the olive growers. A good site for olive growing can be quickly ruined by inappropriate cultivation. This can be clearly yet another key conclusion of our research; although our sample of the people surveyed was perhaps too small, it was in our opinion of high quality and professional.

On the other hand, we believe that our presumptions regarding the aspect's impact either on crop size or on frost threat should not be regarded as too naturally deterministic in a sense that nature predominantly influences certain cultural activities. According to our spatial analysis, the majority of olive groves are situated on locations, classified as very suitable. As the trees are planted by farmers, they are obviously aware of the significance of good geographic (not only topoclimatic) locations and take them into account as well. With this we confirm the last statement from the upper paragraph.

In the future, olive growing will face many potential obstacles, several of which have not been highlighted in our analysis (such as pest attacks and, more important, drought in the light of the forecasted climate change). In the author's opinion, the education, knowledge, will and expert support will be the factors that will play the crucial role in facing the future challenges in the field of olive growing in Slovenia.

TOPOKLIMATSKE RAZMERE KOT DEJAVNIK VPLIVA NA OLJKARSTVO V OBČINI PIRAN

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POVZETEK

Na uspevanje oljk vplivajo številni naravni in družbeni dejavniki. Slovenija je s svojo zemljepisno lego ena izmed najsevernejših rastišč, kjer oljke teoretično še lahko uspevajo in so razmere za njihovo izkoriščanje še gospodarne. Med naravne prištevamo temperaturo zraka, padavine, veter, svetlobo, kamninsko zgradbo ter reliefne oz. topoklimatske dejavnike. Med družbene dejavnike, ki so lahko posledica naravnih, pa prištevamo visoke stroške obdelave nasadov na strmih terenih, parcelno razdrobljenost olj čnih nasadov, neznano lastništvo, manjši ekonomski iztržek od prodaje olja v primerjavi z vinom, itd.

V raziskavi smo si zastavili dva cilja. Prvi je bil predstaviti prostorsko porazdelitev olj čnih nasadov (kot kategorije rabe tal) v občini Piran v luči izbranih reliefnih dejavnikov (nadmorske višine, naklona in ekspozicije). Tu smo uporabili metode računalniške izdelave kart z GIS-om. Drugi cilj je bil ovrednotiti vpliv ekspozicije nasadov na količino pridelka oljk ter na ogroženost zaradi pozeb za območje občine Piran. Ta cilj smo skušali doseči z vprašalniki odprtega tipa med oljkarji z nasadi na različnih ekspozicijah. Dostopni so nam bili le podatki (kontaktni ter o nasadih) tistih oljkarjev, ki imajo nasade prijavljene v GERK. Zaradi pomanjkanja oljkarjev z nasadi na manj primernih ekspozicijah smo anketirali tudi nekaj oljkarjev v občinah Izola in Koper.

Rezultati so pokazali, da so olj čni nasadi kot kategorija rabe tal v občini Piran razporejeni na legah, ki so zelo ugodne zanje. Dobra polovica vseh olj čnikov leži na nadmorski višini do 100 m in nekaj manj kot 98% do višine 250 m. 40% olj čnikov bomo našli na naklonih do 20% (teoretično to pomeni manjše stroške pri obdelavi tal). Slabih 60% jih leži na južnih in jugozahodnih ekspozicijah, spet teoretično bolj osončenih legah, zaščitenih pred močnimi vetrovi (burjo). Rezultati ankete so pokazali, da količino letnega pridelka oljk po drevesu zelo težko jasno in nedvoumno pripišemo zgolj ekspoziciji. Vpliv obstaja, vendar ga je težko oceniti. Podobno velja za možnost pojavljanja pozebe kot dejavnika razporeditve olj čnikov. Olj čniki na manj primernih ekspozicijah so se morda izkazali kot bolj dovzetni za možnost pozebe, a njeno pojavljanje tudi na najbolj ugodnih legah ni povsem izključeno. Na osnovi rezultatov prostorske analize olj čnikov v občini Piran lahko sklenemo, da se oljkarji zavedajo, katere lege so ugodnejše za gojenje oljk.

Ključne besede: oljkarstvo, občina Piran, GERK, pozeba, nadmorska višina, naklon, ekspozicija

REFERENCES

3MAP (2008): Pregledovalnik prostorskih podatkov občine Piran. http://portal.3-port.si/public/trimap/piran/javno/javaClient.3map?file=piran_web_plan_nusz (2008-06)

ArcMAP (2008): Computer and GIS-based application software.

Bandelj Mavsar, D., M. Bučar-Miklavčič, R. Mihelič, M. Podgornik, G. Raffin, N. Režek Donev & V. Valenčič (2008): Sonaravno ravnanje z ostanki pridelave oljk. Knjižnica Annales Majora. Zgodovinsko društvo za južno Primorsko, Znanstveno-raziskovalno središče, Koper, 100 str.

Gabrovec, M. (1996): Sončno obsevanje v reliefno razgibani Sloveniji. Geografski zbornik, 36, 59–68.

Gams, I. (1998): Vreme, sončno obsevanje in temperature. V: Gams, I. & I. Vrišer (ur.): Geografija Slovenije. Slovenska matica, Ljubljana, str. 91–119.

GIAM – Geografski inštitut Antona Melika (2007): Piran municipality vector data. (internal material)

GURS – Geodetska uprava RS (2007): Digital elevation model 12.5m. (internal material)

Jančar, M., M. Sotlar & I. Vrhovnik (2002): Tečaj oljkarstva. Kmetijska svetovalna služba, Koper.

Lubi, G. (2001): Analiza topoklimatskih dejavnikov za uspevanje oljk v Slovenski Istri. Seminarska naloga. Filozofska fakulteta, Univerza v Ljubljani, Ljubljana.

MKGP – Ministrstvo za kmetijstvo, gozdarstvo in prehrano RS (2008): GERK and olive grove stats as a category of land use. (internal material)

Ogrin, D. (1996): Podnebje Slovenske Istre. Knjižnica Annales 11. Zgodovinsko društvo za južno Primorsko, Znanstveno-raziskovalno središče Republike Slovenije, Koper, 320 str.

Ogrin, D. (2002): Pozebe v Primorju z vidika uspevanja mediteranskih kultur. In: Natek, K. (ur.): Dela 18. Filozofska fakulteta, Univerza v Ljubljani, Ljubljana, str. 157–170.

Ogrin, D. (2004): Oljka v Slovenskem Primorju: v primežu podnebja in trenutnih družbeno-ekonomskih razmer. Geografski obzornik, 51(2), 4–10.

Razvojni program podeželja za območje občin Koper, Izola in Piran (2006): Regionalni razvojni center Koper, junij 2006, Koper. http://www.rrc-kp.si/files/RAZVOJNI%20PROGRAM%20PODEZELJA.pdf

Sancin, V. (1990): Velika knjiga o oljki. Založništvo tržaškega tiska, Trst, 319 str.

Vesel, V. (1998): Oljkarstvo v Slovenski Istri. Glasnik ZRS Koper, 3(5), 50–60.

Vrhovnik, I. (2007): Suša je tudi letos prizadela naše oljčnike. Oljka – glasilo Društva oljkarjev Slovenske Istre, 2, 2–4.

OCENE IN POROČILA

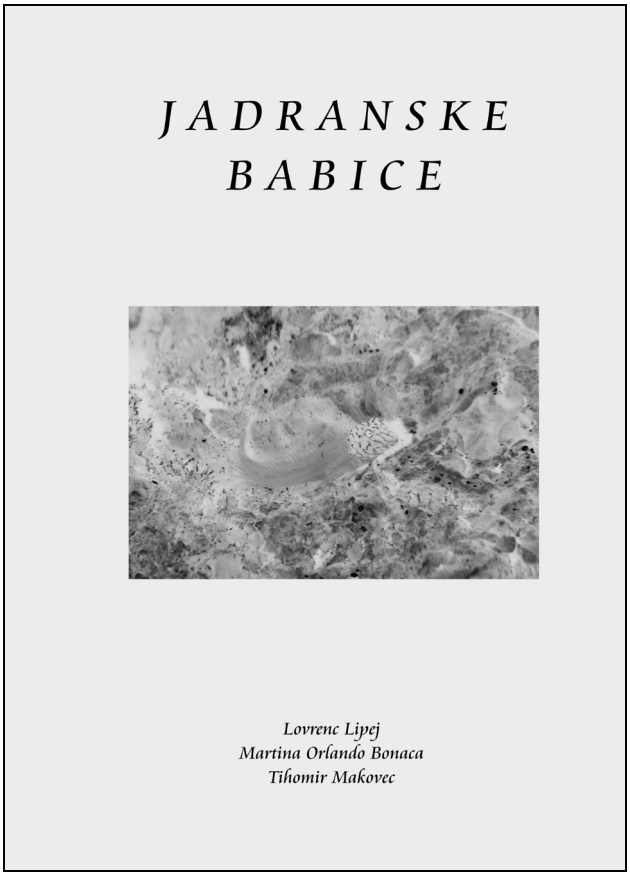
RECENSIONI E RELAZIONI

REVIEWS AND REPORTS

Lovrenc Lipej, Martina Orlando Bonaca, Tihomir Makovec: JADRANSKE BABICE
Nacionalni inštitut za biologijo, Morska biološka postaja, Piran, 2008, 207 str.

Babice? Seveda, saj imamo vendar vsi babice (ali pa smo jih imeli). Vendar ne jadranskih. V tej knjigi gre (predvsem) za morske ribe, ki niso ekonomsko zanimive – torej ne preveč užitne in zatorej dokaj slabo poznane, kot pričnо zgodbo avtorji. Skupna značilnost babic so kožni naglavni izrastki, ki dajejo babicam značilno podobo. Že fotografija na naslovnici da slutiti, da bomo poleg besedila priča tudi bogatemu fotografskemu materialu, in res nas navduši. Še več, publikacija vsebuje poleg bogatih fotografij tudi detajlne skice, ki opozarjajo na pestrost jadranskih babic slovenskega morja.

Z zgodovino raziskovanja babic v Jadranskem morju smo opozorjeni na številne raziskovalce, ki so te ribe raziskovali že konec 19. stoletja, avtorji sami pa so dodali "piko na i" z raziskavami v novejšem obdobju. Predstavljenih je 21 vrst babic iz treh družin, ki poleg pravih babic vključujejo še sprehajalčke in luskaste babice ter tako zajamejo babice v širšem smislu. Avtorji vsako vrsto predstavijo in opišejo posebej, najpomembnejše značilnosti pa lahko opazujemo tudi na fotografijah, ki so le z redkimi izjemami posnete pod vodno gladino. Poleg osnovnih značilnosti za vsako vrsto izvemo vse o njeni razširjenosti in življenjskem prostoru. Priložena slika globinske razporeditve pa nas opozarja, kje osebke posamezne vrste lahko pričakujemo. Na koncu opisov posameznih vrst so izčrpno navedeni viri, s preglednim določevalnim ključem pa nam je omogočena tudi neposredna primerjava in razlikovanje vrst babic.



Ena izmed posebnosti morskih babic, ki zagotovo pritegne vsakogar, je njihova živo pisana obarvanost. Ker mnoge živijo v plitvih vodah do enega metra globine, bi pričakovali, da so zlahka opazne. Avtorji navajajo, da številne resnično so, vendar predvsem samci, in še to le v obdobju parjenja, ko so ozaljšani z barvnim svatovskim vzorcem. Pogosteje babice uporabljajo t.i. kriptični barvni vzorec, ki ga lahko spreminjajo v skladu z okoljem, zato babice sivih, rjavih, olivno zelenih ali rumenih barv na enako obarvani podlagi težko opazimo. Če pa jih, potem nas pogosto opazujejo iz lupin školjk, razpok med skalami ali rovov, ki so jih naredili morski datlji. "Skrivanje" jim omogoča preživetje v turbulentnih razmerah plitvih vod. Pisanost je tudi vzrok, da so babice priljubljene akvarijske živali. Za vse, ki jih zanimajo takšne živali, so avtorji napisali tudi navodila za pripravo in vzdrževanje ustreznega akvarija.

Publikacija pa ni le lepa knjiga, ki opisuje značilnosti in posebnosti babic, marveč je vanjo vključeno tudi poglavje o raziskovanju babic, kjer so predstavljene metode vzorčevanja, prikazana pa je tudi uporaba statističnih metod. Čeprav se avtorji posvečajo raziskavam morja, niso v publikaciji pozabili niti na rečno babico, našo edino vrsto, ki živi v sladkih in brakičnih vodah oz. je živela, saj so najstarejši podatki o njej stari že več kot sto let. Ogroženost drugih vrst je posredna, saj je njihova pestrost tesno povezana s pestrostjo habitatov. Za vse, ki jih stvari morda zanimajo še podrobneje, so na koncu knjige avtorji pripravili obsežen seznam literature, za vse strokovne izraze pa slovar z razlago. Publikacijo zaključujeta indeksa slovenskih in latinskih imen. Temu sledi le še zahvala s seznamom avtorjev fotografij. Le redkim avtorjem se posreči za vsakega ljubitelja morja smiselno združiti zanimiv opisni del z znanstveno raziskovalno vsebino, vse to pa nadgraditi z bogatimi fotografijami in ilustracijami. Avtorjem te publikacije je to več kot uspelo, zato je publikacija resnično prava monografija, ki preseže mnoga pričakovanja.

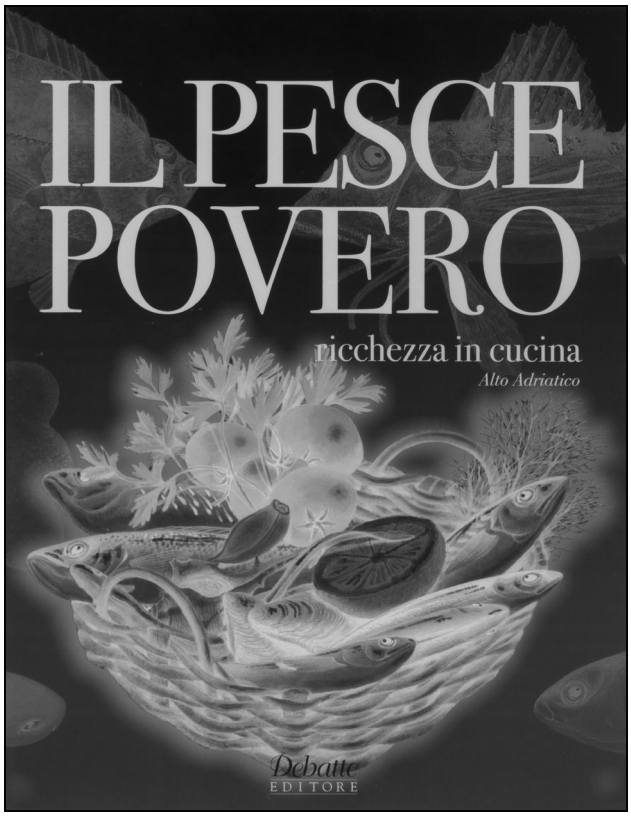
Gorazd Urbanič

IL PESCE POVERO, RICCHEZZA IN CUCINA.
Edizione per l'Alto Adriatico.
[a cura di: Silvia Di Batte, Fulvio Venturi, Maurizio Spoto, Roberto Odorico, Paolo Sartor, Alessandro Ligas, Mario Sbrana e Ilaria Rossetti] Debatte Editore, 2008, 166 p.

Il volume, una guido bio-culinaria delle specie marine del Nord Adriatico, viene dedicato a tutti coloro che ancora amano recarsi in pescheria, almeno il sabato mattina, per acquistare pesce fresco del »mare nostrum«. Personalmente saluto con immenso piacere la pubblicazione di tale libro, in quanto rientro in quella fetta di popolazione locale che teme che col tempo possano venire cancellate le tradizioni che i nostri nonni e bisnonni, con tanta saggezza, ci hanno tramandato. Tradizioni indispensabili per poter vivere in simbiosi con questa fetta di mare così piccola eppur così ricca dal punto di vista della biodiversità marina. Non appena ho sfogliato il libro, arricchito dalle meticolose illustrazioni di Rossella Faleni e Sabrina Barsotti, nella mente ho riassaporato il gusto e l'odore del brodetto che quasi ogni domenica mia nonna, con infinita pazienza, preparava per l'intera grande famiglia. Brodetto ricchissimo di specie di pesce povero, che mio nonno con grande passione e rispetto pescava.

Nella parte introduttiva del volume, Maurizio Spoto e Roberto Odorico si premurano di sottolineare l'importanza di far conoscere nuovamente le specie ittiche locali, non più consumate a causa del sempre crescente mercato di prodotti congelati o inscatolati, la cui provenienza spesso rimane ignota. Gli autori sostengono le iniziative finalizzate a promuovere il pesce povero, in quanto ha una bassa impronta ecologica rispetto a un prodotto che deve viaggiare migliaia di chilometri in aereo o camion refrigerati per arrivare al consumatore. Sottolineano inoltre, come il consumo di un prodotto locale possa contribuire a preservare le condizioni ideali di vita degli stock ittici. Col termine pesce povero vengono qui accomunate specie di pesci ossei e cartilaginei, molluschi (cefalopodi, bivalvi, gasteropodi) e crostacei.

Nella parte centrale del libro troviamo presentati per 44 specie di pesce povero le caratteristiche generali, le differenze rispetto alle specie affini, l'habitat e la distribuzione geografica, cenni sulla biologia e l'ecologia e note sulla pesca. Le descrizioni vengono arricchite, come già menzionato, dalle illustrazioni e dai nomi regionali ed internazionali per ogni singola specie.



La terza parte del libro viene dedicata alle ricette, divise in ricette di base (utili per cucinare alcune specie per le quali la tradizione non ci ha tramandato ricette specifiche), ricette di pesce povero (riferite concretamente alle specie trattate nel libro) e ricette della tradizione (riguardanti specie di grande consumo ma di basso valore).

La prima edizione del libro è andata a ruba, il che testimonia che la popolazione locale non vuole veder naufragare il patrimonio delle tradizioni centennali ed è forse pronta, col sostegno della comunità scientifica, ad innescare, come dice Roberto Odorico, "processi di cambiamento". Processi finalizzati alla corretta gestione delle risorse alieutiche e alla riscoperta delle nostre tradizioni culinarie, che aggiungono immenso valore alla cultura dell'Alto Adriatico.

Martina Orlando Bonaca